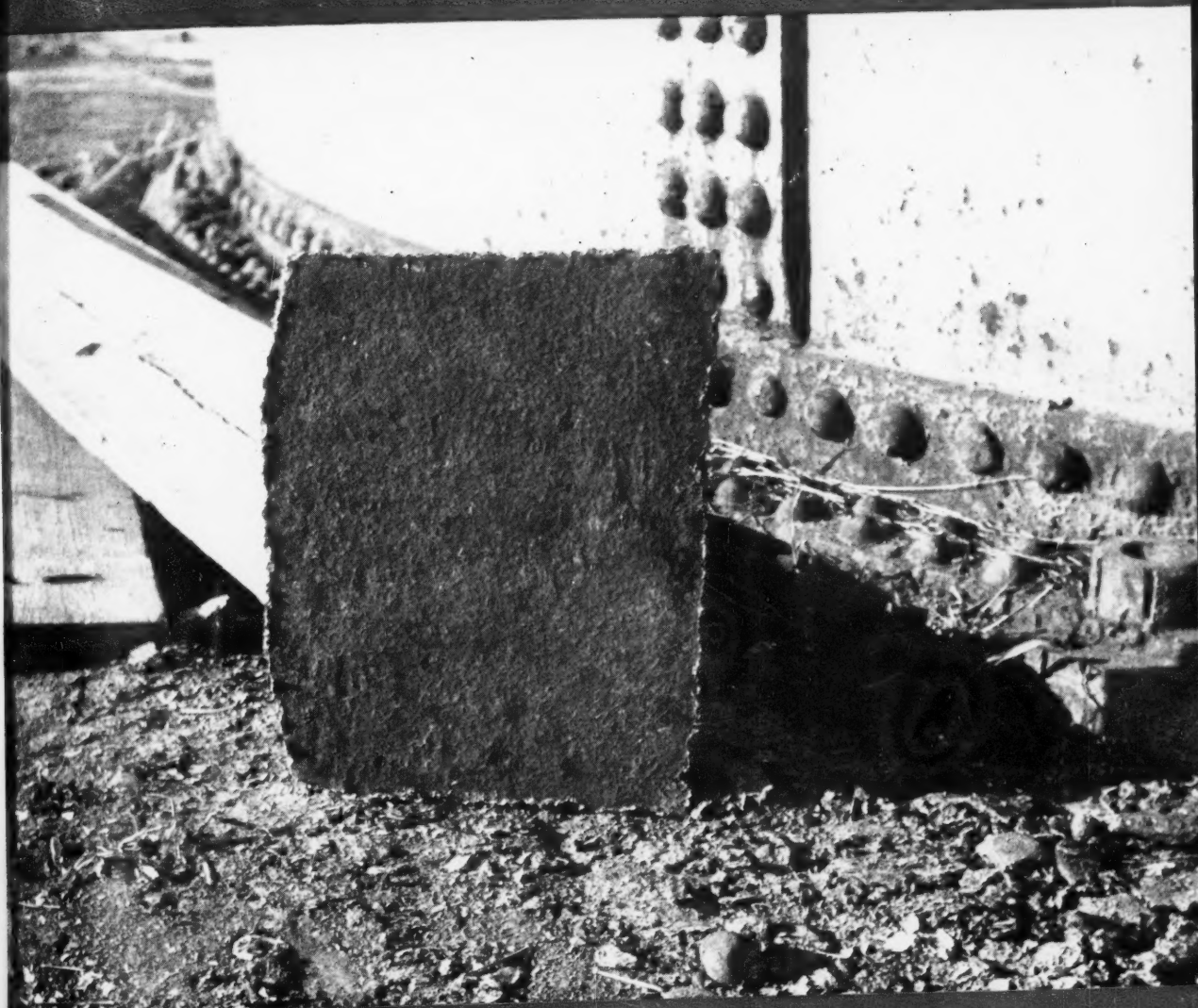


# Corrosion

Official Publication  
NATIONAL ASSOCIATION OF CORROSION ENGINEERS



JULY, 1956

No. 7

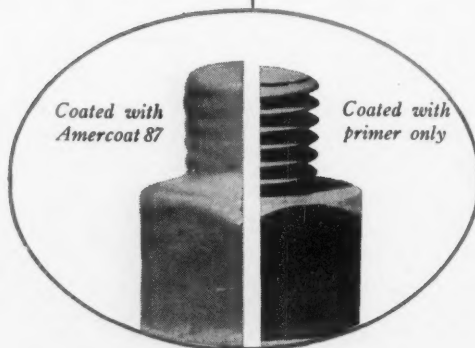
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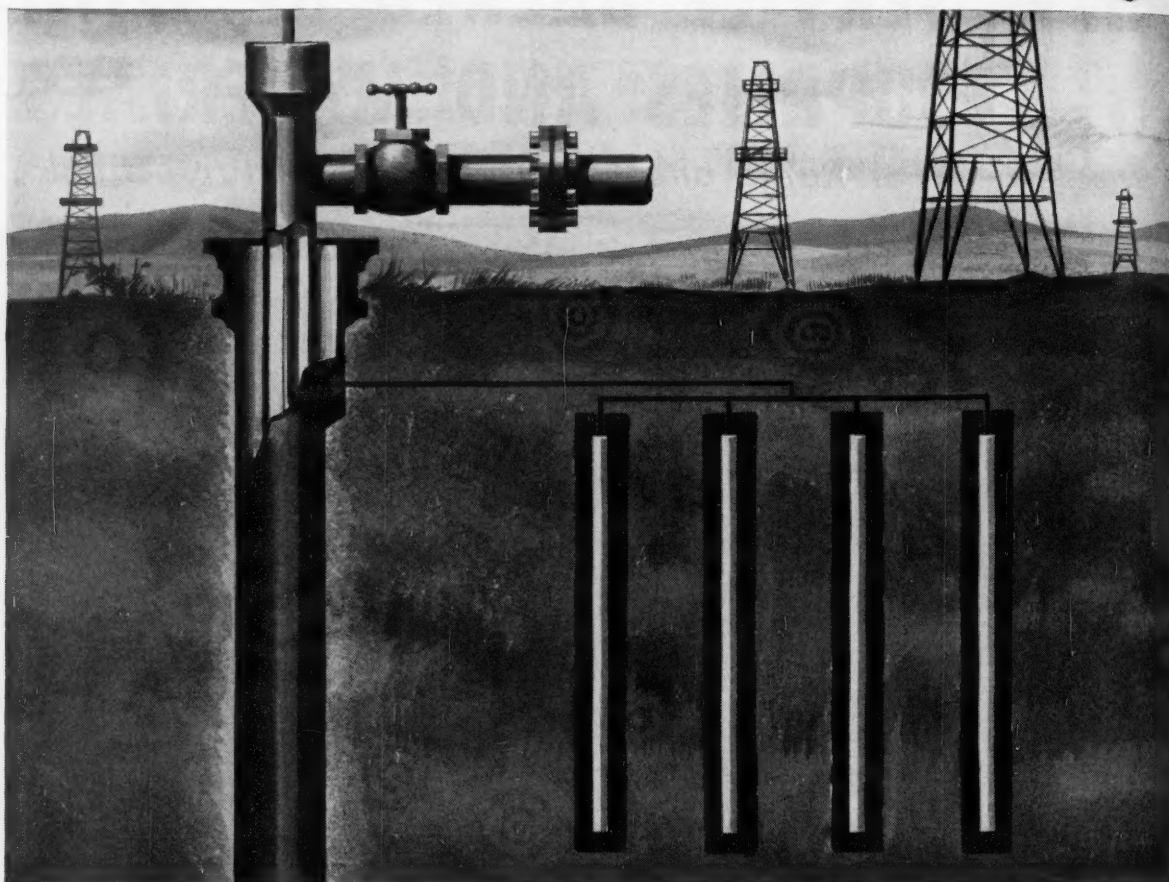
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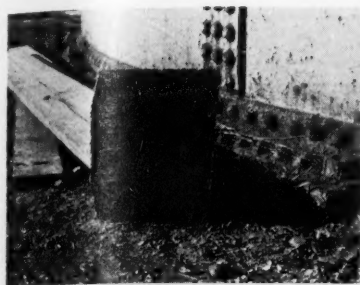
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Corrosion I



**THIS MONTH'S COVER**—The oblong piece of metal shown here was cut from about two-thirds of the way up an 800,000 gallon water stand-pipe recently razed by the city of Houston. It shows (after cleaning) virtually no corrosion damage after about 70 years' service. None of the wrought iron plates of this tank showed anything but superficial corrosion attack. (See Page 99 News Section for more data.)



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U. S. for an equivalent amount in U. S. funds. En-  
tered as second class matter October 31, 1946, at the  
Post Office at Houston, Texas, under the act of March  
3, 1879.

Corrosion Is Indexed Regularly by Engineering Index.

# Corrosion

devoted entirely to corrosion  
research and control

Published monthly as its official journal, by the National  
Association of Corrosion Engineers, Inc., at Houston, Texas,  
U. S. A., as a permanent record of progress in corrosion control.



Vol. 12

July, 1956

No. 7

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# Directory of NACE Technical Committees

## Technical Practices Committee

C. P. Larrabee, Chairman, Applied Research Laboratory, United States Steel Corporation, Monroeville, Pennsylvania.  
E. C. Greco, Vice Chairman, United Gas Corp., Box 1407, Shreveport, La.  
W. H. Stewart, Vice President NACE, Sun Pipe Line Co., Sun Oil Co., San Jacinto Bldg., Beaumont, Texas.  
Chairmen of T-1 through T-6 also are members of this committee.

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Jack L. Battle, Vice Chairman, Humble Oil & Refining Co., Box 2180, Houston, Texas.

## T-1A Corrosion in Oil and Gas Well Equipment, Los Angeles Area

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H. J. Kipp, Vice-Chairman, General Petroleum Corp., Box 2122, Terminal Annex, Los Angeles, Cal.

## T-1B Condensate Well Corrosion

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D. R. Fincher, Vice-Chairman, Tide Water Associated Oil Co., Weimar, Texas.

## T-1C Sweet Oil Well Corrosion

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Rado Loncaric, Vice Chairman, Atlantic Refining Co., Box 2819, Dallas, Texas.

## T-1D Sour Oil Well Corrosion

R. E. Lembecke, Chairman, Cities Service Research & Development Co., 920 East Third Street, Tulsa, Okla.  
J. V. Gannon, Vice Chairman, The Texas Co., Box 1270, Midland, Texas.

## T-1D-1 Fundamentals of Corrosion

J. D. Sudbury, Chairman, Production Research Division, Development and Research Dept., Continental Oil Company, Ponca City, Oklahoma.

## T-1F Metallurgy

Monte Kaplan, Chairman, Atlantic Refining Co., Box 2819, Dallas, Texas.  
H. M. Cooley, Vice-Chairman, Bethlehem Steel Co., Box 2171, Tulsa, Okla.

## T-1G Sulfide Stress Corrosion Cracking

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J. J. B. Rutherford, Vice-Chairman, Tubular Products Div., The Babcock and Wilcox Co., Beaver Falls, Pa.

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## T-1H-2 Oil String Casing Corrosion, West Kansas Area

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## T-1H-3 Oil String Casing Corrosion, East Texas Area

M. J. Olive, Chairman, Arkansas Fuel Oil Corp., Shreveport, La.

## T-1H-4 Oil String Casing Corrosion, California Area

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## T-1J Oil Field Structural Plastics

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## T-2C Minimum current requirements

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## T-2D Standardization of Procedures for Measuring Pipe Coating Leakage Conductance

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## T-2E Internal Corrosion of Product Pipe Lines and Tanks

Ivy M. Parker, Chairman, Plantation Pipe Line Co., Box 1743, Atlanta, Georgia.  
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## T-2F Internal Corrosion of Crude Oil Pipe Lines and Tanks

J. C. Watts, Jr., Chairman, Internal Pipeline Maint. Company, Box 186, Odessa, Texas.

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## T-3A Corrosion Inhibitors

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S. K. Coburn, Vice Chairman, Association of American Railroads, 3140 S. Federal St., Chicago, Illinois.

## T-3A-1 General Theory of the Action of Corrosion Inhibitors

W. W. Sweet, Chairman, Research & Development Dept., Colgate Palmolive Co., 105 Hudson St., Jersey City, N. J.

## T-3A-2 Methods of Testing & Screening Corrosion Inhibitors

(Chairman to be Selected)

## T-3A-3 Materials Available for and Application of Corrosion Inhibitors

Lyle Timm, Chairman, Sharples Chemicals, Inc., Box 151, Wyandotte, Mich.

## T-3B Corrosion Products

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## T-3C Annual Losses Due to Corrosion

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## T-3D Instruments for Measuring Corrosion

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## T-3E-1 Corrosion of Railroad Tank Cars

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L. R. Honnaker, Vice Chairman, Engineering Materials Group, Eng. Dept., E. I. du Pont de Nemours & Co., Inc., 13W10 Louviers Bldg., Wilmington, Del.

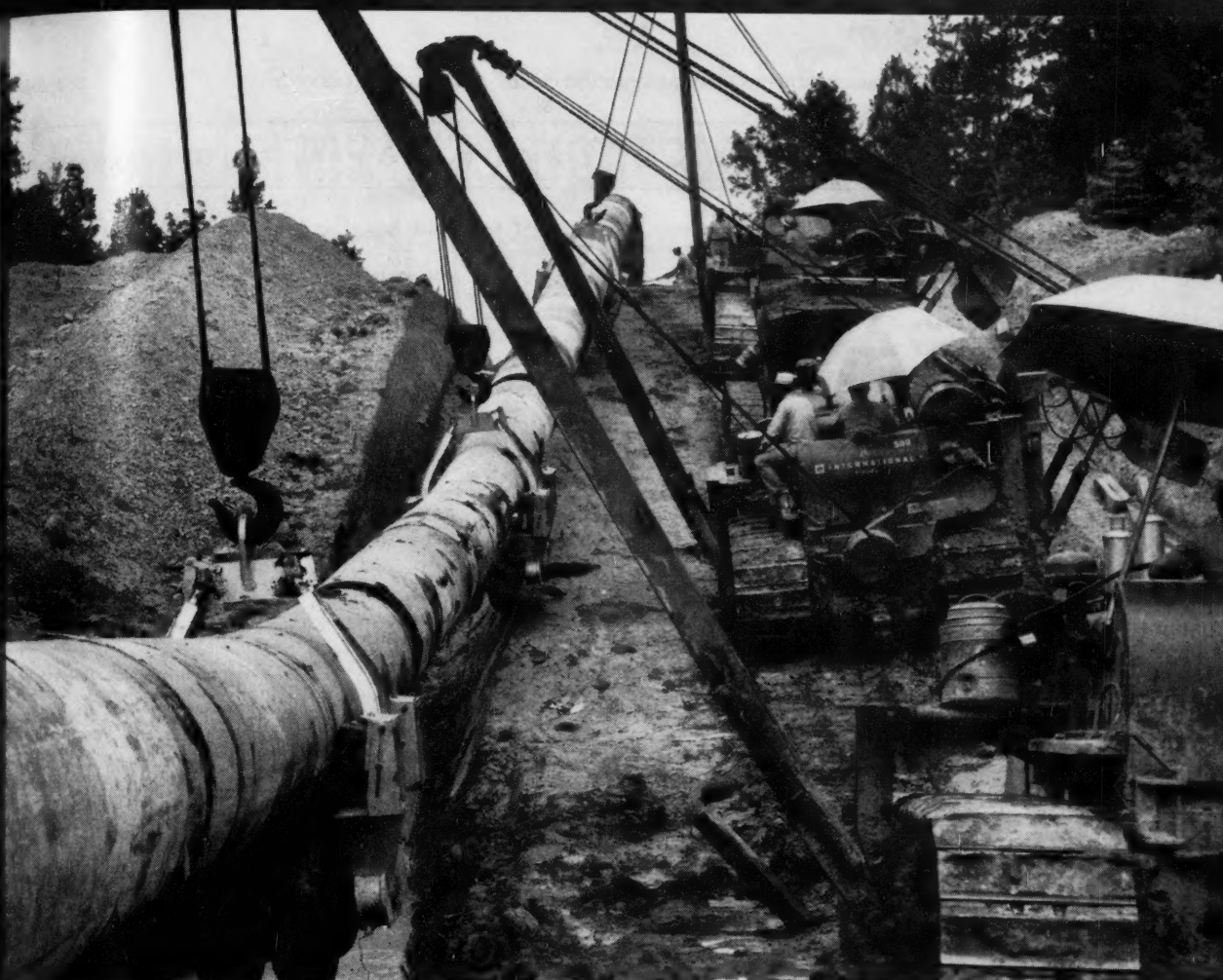
## T-3E-2 Corrosion in Railroad Hopper Cars

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(Continued From Page 4)

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## T-3G-1 Cathodic Protection of Hull Bottoms of Ships

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## T-3G-2 Cathodic Protection of Heat Exchangers

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## T-3G-3 Cathodic Protection of Process Equipment

A. A. Brouwer, Chairman, The Dow Chemical Co., Midland, Michigan.

## T-3H Tanker Corrosion

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## T-4 UTILITIES

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## T-4A Effects of Electrical Grounding on Corrosion

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## T-4B Corrosion of Cable Sheaths

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D. T. Rosselle, Vice Chairman, Southern Bell Telephone & Telegraph Co., 1424 Hurt Building, Atlanta, Ga.

## T-4B-1 Lead and Other Metallic Sheaths

T. J. Mattland, Chairman, American Telephone & Telegraph Co., 32 Avenue of the Americas, New York 13, New York.

## T-4B-2 Cathodic Protection

R. M. Lawall, Chairman, Amer. Tel. & Tel. Co., 1538 Union Commerce Bldg., Cleveland 14, Ohio.  
J. J. Pokorny, Vice Chairman, Cleveland Elec. Illuminating Co., 75 Public Sq., Cleveland 1, Ohio.

## T-4B-3 Tests and Surveys

D. R. Werner, Chairman, American Telephone & Telegraph Co., 324 East 11th Street, Room 1701, Kansas City, Mo.

## T-4B-4 Protection of Pipe Type Cables

H. W. Dieck, Chairman, Long Island Lighting Company, 175 Old Country Road, Hicksville, New York.  
J. B. Prime, Jr., Vice Chairman, Florida Power & Light Co., Box 3100, Miami, Florida.

## T-4B-5 Non-Metallic Sheaths and Coatings

G. H. Hunt, Chairman, Simplex Wire & Cable Co., 79 Sidney St., Cambridge 39, Massachusetts.

## T-4B-6 Stray Current Electrolysis

J. Svetlik, Chairman, Northern Indiana Public Service Co., 5265 Hohman Ave., Hammond, Indiana.  
G. H. Cantwell, Vice Chairman, Indiana Bell Telephone Co., 240 N. Meridian St., Indianapolis, Indiana.

## T-4D Corrosion by Deicing Salts

D. W. Kaufmann, Chairman, International Salt Co., Inc., 638 Marine Trust Bldg., Buffalo, New York.  
W. H. Bruckner, Vice Chairman, University of Illinois, Urbana, Illinois.

## T-4E Corrosion by Domestic Waters

T. E. Larson, Chairman, Illinois State Water Survey, Box 232, Urbana, Illinois.

## T-4F Materials Selection for Corrosion Mitigation in the Utility Industry

F. E. Kulman, Temporary Chairman, Consolidated Edison Co. of New York, Inc., 4 Irving Place, New York, N. Y.

## T-4F-1 Materials Selection in the Water Industry

Daniel Cushing, Chairman, 148 State St., Boston, Massachusetts.

## T-4F-2 Materials Selection in the Electric Industry

L. P. Shaefer, Chairman, The Hinchman Corp., Francis Palms Bldg., Detroit, Mich.

## T-5 Corrosion Problems in the Process Industries

Wm. G. Ashbaugh, Chairman, Carbide & Carbon Chemicals Co., Texas City, Texas.

R. I. Zimmerer, Vice Chairman, Petro-Tex Chemical Corp., Box 2584, Houston 1, Texas.

## T-5A Chemical Manufacturing Industry

R. I. Zimmerer, Vice Chairman, Petro-Tex Chemical Corp., Box 2584, Houston 1, Texas.  
A. C. Hamstead, Vice Chairman, Carbide & Carbon Chemicals Co., South Charleston, West Virginia.

## T-5A-1 Sulfuric Acid

C. L. Bulow, Chairman, Bridgeport Brass Co., 30 Grand St., Bridgeport, Conn.  
W. A. Luce, Vice Chairman, The Durilon Co., Box 1019, Dayton, Ohio.

## T-5A-3 Acetic Acid

H. O. Teeple, Chairman, The International Nickel Co., Inc., 67 Wall St., New York, New York.

## T-5A-4 Chlorine

Wayne Inbody, Chairman, Diamond Alkali Co., Box 348, Painesville, Ohio.

## T-5A-5 Nitric Acid

J. L. English, Chairman, Oak Ridge National Laboratory, Box P, Oak Ridge, Tenn.  
W. H. Burton, Vice Chairman, General Chemical Division, Allied Chemical & Dye Corp., Camden, New Jersey.

## T-5A-6 HF Corrosion

T. L. Hoffman, Chairman, Phillips Petroleum Co., Atomic Energy Div., Box 1259, Idaho Falls, Idaho.

## T-5B High Temperature Corrosion

E. N. Skinner, Chairman; The International Nickel Co., Inc., 67 Wall St., New York, N. Y.  
J. L. McPherson, Vice-Chairman, 427 Murdock Ave., R.F.D. 2, Library, Pa.

## T-5B-2 Sulfide Corrosion at High Temperatures and Pressures in the Petroleum Industry

M. E. Holmberg, Chairman, 4101 San Jacinto St., Houston, Texas.

## T-5B-3 Oil Ash Corrosion

R. T. Foley, Chairman, General Electric Co., Schenectady, New York.

## T-5B-5 Corrosion by Molten Salts and Metals

W. D. Manly, Chairman, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

## T-5C Corrosion by Cooling Waters

## T-5C-1 Corrosion by Cooling Waters (South Central Region)

C. P. Dillon, Chairman, Carbide & Carbon Chemicals Co., Texas City, Texas.  
M. Brooke, Vice-Chairman; Phillips Petroleum Co., Box 379, Old Ocean, Texas.  
W. W. Wheeler, Secretary; Rohm & Haas, Box 672, Pasadena, Texas.

## T-5D Plastic Materials of Construction

S. W. McIlrath, Chairman, 151 East 214th St., Euclid, Ohio.  
R. E. Gackenbach, Vice-Chairman, American Cyanamid Co., Organic Chemical Div., Bound Brook, N. J.  
J. S. McBride, Secretary, Owens-Corning Fiberglass Corp., 598 Madison Avenue, New York 22, New York.

## T-5D-1 Questionnaires

S. W. McIlrath, Chairman, 151 E. 214th Street, Euclid 23, Ohio.

## T-5D-2 Inorganic Acids

R. L. Hughes, Chairman, Spencer Chemical Co., 1231 Woodsdewer Rd., Kansas City, Missouri.  
J. F. Malone, Secretary, B. F. Goodrich Chemical Co., 2960 East Ninth Street, Cleveland 15, Ohio.

## T-5D-3 Inorganic Alkalies

Peter Klmen, Chairman, Champion Paper & Fibre Co., Box 872, Pasadena, Texas.  
L. B. Connelly, Secretary, Eastman Chemical Products Company, 704 Texas National Bank Building, Houston 2, Texas.

## T-5D-4 Gases

Beaumont Thomas, Chairman, Stebbins Eng. & Mfg. Co., Eastern Blvd., Watertown, New York.  
J. L. Forse, Vice Chairman, Dow Chemical Company, Plastics Technical Service, Midland, Michigan.  
William Eakins, Secretary, Chemical Corporation, Plastics Division, West Warren, Massachusetts.

## T-5D-5 Water and Salt Solutions

Paul Elliott, Chairman, Naugatuck Chemical Company, Kralastic Development, Naugatuck, Conn.

## T-5D-6 Organic Chemicals

B. B. Pusey, Vice-Chairman, Bakelite Co., Div. of U.C.C., Bound Brook, New Jersey.  
Wade Wolfe, Jr., Secretary, 73 Ermann Drive, Buffalo 17, New York.

## T-5D-7 Engineering Design

O. H. Fenner, Chairman, Monsanto Chemical Company, 1700 South Second Street, St. Louis 4, Missouri.  
K. A. Phillips, Vice-Chairman, American Zinc, Lead & Smelting Co., P. O. Box 495, East St. Louis, Illinois.  
W. B. Meyer, Secretary, St. Louis Metallizing Co., 625 South Sarah, St. Louis 16, Missouri.

## T-5D-8 Methods and Criteria for Evaluating Plastics in Chemical Environment

R. F. Clarkson, Chairman, Olin Mathieson Chemical Corp., Mathieson Building, Baltimore, Md.  
R. Lembeck, Secretary, Cities Service Res. & Dev. Co., 929 East Third, Tulsa 3, Oklahoma.

## T-5E Stress Corrosion Cracking of Austenitic Stainless Steel

L. Miller Rogers, Chairman, Union Carbide & Carbon Chemical Co., Box 471, Texas City, Texas.

## T-6 Protective Coatings

L. L. Whiteneck, Chairman, Long Beach Harbor Dept., 1333 El Embarcadero, Long Beach, California.  
L. S. Van Delinder, Vice Chairman, Carbide & Carbon Chemicals Co., South Charleston, West Va.

## T-6A Organic Coatings and Linings for Resistance to Chemical Corrosion

R. McFarland, Jr., Chairman, Hills-McCanna Co., 3025 N. W. Ave., Chicago 18, Illinois.  
C. G. Munger, Vice-Chairman, Amercoat Corp., 4809 Firestone Blvd., South Gate, Calif.  
L. A. Ferris, Secretary, E. I. DuPont de Nemours & Co., Inc., Polychemicals Dept., Wilmington, Delaware.

## T-6A-1 Heavy Linings

H. C. Klein, Chairman, B. F. Goodrich Co., Cuyahoga Falls, Ohio.

## T-6-2 Vinyl Coatings

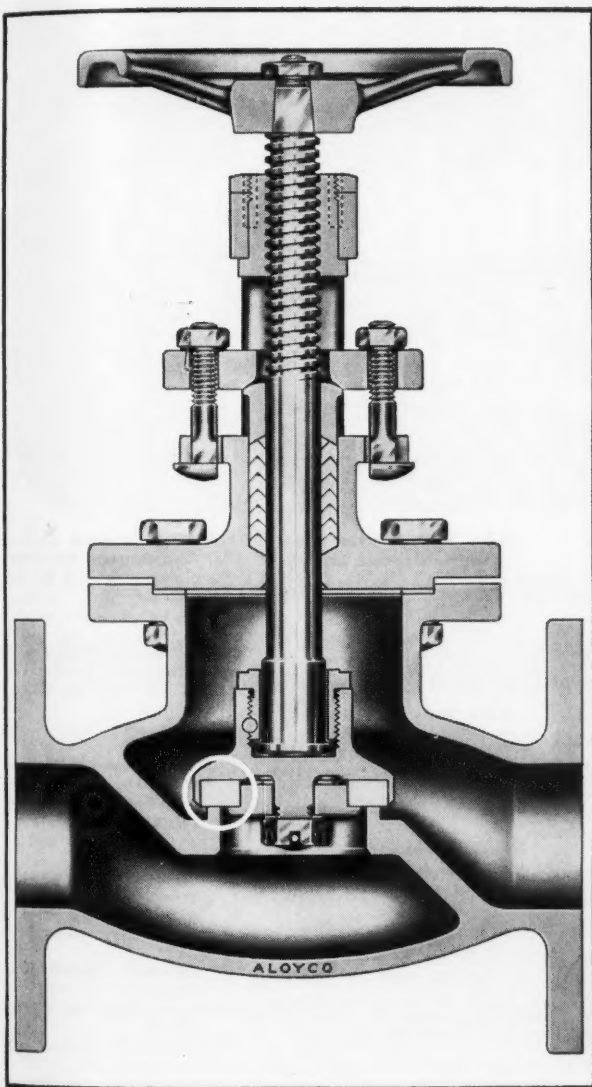
K. Tator, Chairman, 2020 Montour Street, Coraopolis, Pa.

(Continued on Page 8)



# Teflon\* forms gas-tight seal in corrosion resistant Aloyco valves

\*Registered DuPont trademark.



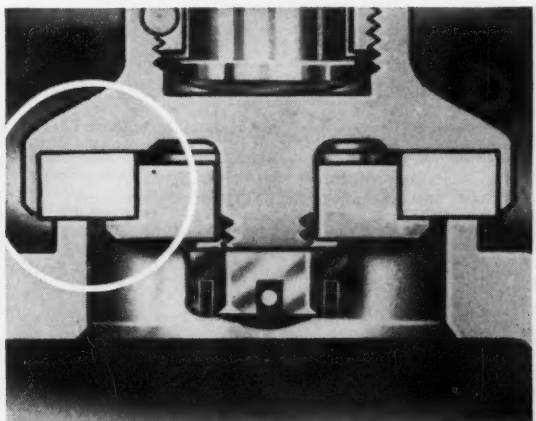
Hard-to-hold volatile or elusive fluids—even if highly corrosive—can't leak past the Teflon discs or packing in this Aloyco valve.

The reason? Teflon's ability to form a gas-tight seal under compression—even when the seating surface or adjoining metal is slightly corroded. That's why Teflon-equipped valves outlast and outperform valves with metal-to-metal seating surfaces in handling volatile corrosive fluids.

Add to that the fact that Teflon has high impact strength under hydraulic shock loads, and is inert to almost all chemicals up to 500° F., and you'll see why Aloyco pioneered the use of this unique material for discs, seats and packing in corrosion-resistant valves.

Aloyco valves with renewable Teflon discs, seats, and packing come with screwed or flanged ends in a variety of styles: globe, Y, angle, swing-check, needle, plug-gate—as well as sampling valves. You'll find them all described in our new bulletin No. 11. Mail coupon below for your copy.

64



**ALOYCO GLOBE VALVE** holds Teflon disc securely against possible overload.

Longer Lasting

**ALOYCO**

VALVES

1ST IN CORROSIVE SERVICE

Subsidiary of Walworth Company

**Alloy Steel Products Company, Inc.**  
1304 West Elizabeth Avenue  
Linden, New Jersey

Gentlemen:  
Please send me a free copy of your new Bulletin No. 11 on Aloyco valves with renewable Teflon discs or seats.

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**Experience can  
keep you out of trouble  
in fighting corrosion, too.**

Why gamble with "unknown quantities" when it comes to protecting pipe, pipe joints, couplings and other vulnerable surfaces above and below ground?

Since 1941, TAPECOAT, the quality coal tar coating in handy tape form, has demonstrated its ability to withstand corrosion year after year. In case after case, TAPECOATED lines have been dug up after 10 years of service with no signs of deterioration on the pipe surfaces uncovered. That's why TAPECOAT is specified by those who know that continuing protection is the first consideration.

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**The  
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of  
Coal Tar  
Coating in  
Tape Form

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## Directory of Technical Committees

(Continued From Page 6)

### • T-6A-3 Vinylidene Chloride Polymers

R. L. Brown, Chairman, The Dow Chemical Co., Midland, Mich.

### • T-6A-4 Phenolics

F. Baskett, Chairman, 4334 Ella Blvd., Houston, Texas.

### • T-6A-5 Polyethylene

L. S. Van Delinder, Chairman, Carbide & Carbon Chemicals Co., South Charleston, West Va.

### • T-6A-6 Rubber and Elastomers

H. C. Klein, Chairman, B. F. Goodrich Co., Cuyahoga Falls, Ohio.

### • T-6A-7 Silicones

R. McFarland, Jr., Chairman, Hills-McCanna Co., 3025 N. Western Ave., Chicago, Ill.

### • T-6A-8 Methacrylates

• T-6A-9 Furanes  
F. Baskett, Chairman, 4334 Ella Blvd., Houston, Texas.

### • T-6A-10 Polyesters

D. D. Cone, Chairman, Insul-Mastic Corp. of America, 7750 W. 61st Place, Summit, Ill.

### • T-6A-11 Epoxys

C. G. Munger, Chairman, Amercoat Corp., 4809 Firestone Blvd., South Gate, Calif.

### • T-6A-12 Fluorocarbons

L. A. Ferris, Chairman, E. I. Du Pont de Nemours & Co., Inc., Wilmington, Delaware.

### • T-6A-13 Asphalts-Bituminous

C. U. Pittman, Chairman; Koppers Co., Inc., Tar Products Div., Tech. Dept., Box 128, Verona, Pa.

### • T-6A-14 Organic-Brick Covered

R. W. Hall, Chairman; Stebbins Engr. & Mfg. Co., 363 Eastern Blvd., Watertown, N. Y.

### T-6B Protective Coatings for Resistance to Atmospheric Corrosion

Howard C. Dick, Chairman, Products Research Service, Inc., Box 6116, New Orleans, La.  
R. S. Freeman, Vice-Chairman; Cities Service Refining Corp., Box 1562, Lake Charles, La.

### T-6C Protective Coatings for Resistance to Marine Corrosion

Raymond P. Devoluy, Chairman, The Glidden Co., Room 1310, 52 Vanderbilt Avenue, New York 17, New York.  
R. F. Daw, Vice Chairman, The Texas Co., 135 East 42nd St., New York 17, New York.

### T-6D Industrial Maintenance Painting

J. C. Coffin, Chairman; The Dow Chemical Co., Bldg. 4-298, Midland, Mich.

### T-6E Protective Coatings in Petroleum Production

F. T. Rice, Chairman, The Pure Oil Co., 35 E. Wacker Drive, Chicago, Ill.  
D. F. Dial, Jr., Vice-Chairman; The Pure Oil Co., Box 239, Houston, Texas

### T-6G Surface Preparation for Organic Coatings

S. E. Jack, Chairman, Aluminum Laboratories, Ltd., Box 84, Kingston, Ontario, Canada.

S. C. Frye, Vice Chairman, Research Dept., Bethlehem Steel Co., Bethlehem, Pa.

### T-6H Glass Linings and Vitreous Enamels

G. H. McIntyre, Chairman, Ferro-Enamel Corporation, 4150 East 56th Street, Cleveland, Ohio.

### T-6K Corrosion Resistant Construction With Masonry and Allied Materials

L. R. Honnaker, Chairman, E. I. Du Pont de Nemours Company, Inc., Eng. Dept., 13W10 Louviers Bldg., Wilmington, Del.  
George P. Gabriel, Vice Chairman, Atlas Mineral Products Company, Mertztown, Pa.

### T-6R Protective Coatings Research

Joseph Bigos, Chairman, Steel Structures Painting Council, Mellon Inst., 4400 Fifth Ave., Pittsburgh 13, Pa.

### T-7 Underground Corrosion Coordinating Committee

J. M. Fouts, Chairman, New York Telephone Company, 63 E. Delavan Avenue, Buffalo, New York.

C. A. Erickson, Jr., Vice Chairman, The Peoples Natural Gas Company, 140 Stanwix Street, Pittsburgh, Pa.

### T-7A Northeast Region Underground Corrosion Coordinating Committee

C. A. Erickson, Jr., Chairman, The Peoples Natural Gas Company, 140 Stanwix Street, Pittsburgh, Pa.  
L. Andrew Kellogg, Vice-Chairman; Niagara Mohawk Power Corp., 300 Erie Blvd., West, Syracuse, N. Y.

### T-7B North Central Region Underground Corrosion Coordinating Committee

(Officers not yet selected)

### T-7C Southeast Region Underground Corrosion Coordinating Committee

(Officers not yet selected)

### T-7D South Central Region Underground Corrosion Coordinating Committee

(Officers not yet selected)

### T-7E Western Region Underground Corrosion Coordinating Committee

(Officers not yet selected)

### T-7F Canadian Region Underground Corrosion Coordinating Committee

(Officers not yet selected)

## BACK ISSUES OF VOLUME 11

Copies of back issues of Volume 11, January-December, 1955 are available except July. Persons who customarily bind all or parts of Corrosion and who lack issues to make the volume complete may get back copies at the following prices per copy, postpaid, remittance in advance: NACE members, 50 cents; Non-members, \$1. An additional charge of 65 cents per package is made for mailings to addresses outside the United States, Canada and Mexico.

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## COLUMBIA-SOUTHERN SODIUM CHROMATE PREVENTS CORROSION

Costly shutdowns and expensive replacement of equipment are often the price to be paid when corrosion attacks closed or recirculating systems.

Soluble Columbia-Southern sodium chromate inhibits metallic corrosion caused by the exposure of iron, steel or bimetallic systems to various types of water or salt solutions.

Columbia-Southern sodium chromate is simply dissolved in the solution in the system. Immediately a protective film is formed on the metal parts. If, for any reason, this film is scratched or broken, the sodium chromate present in the solution instantly seals it again.

Use Columbia-Southern sodium chromate to effectively and economically guard your systems against costly corrosion. Write today for further information to the Pittsburgh address or to any of the district offices.

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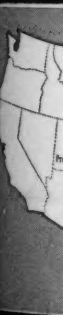
In CANADA: Standard Chemical Limited  
and its Commercial Chemicals Division

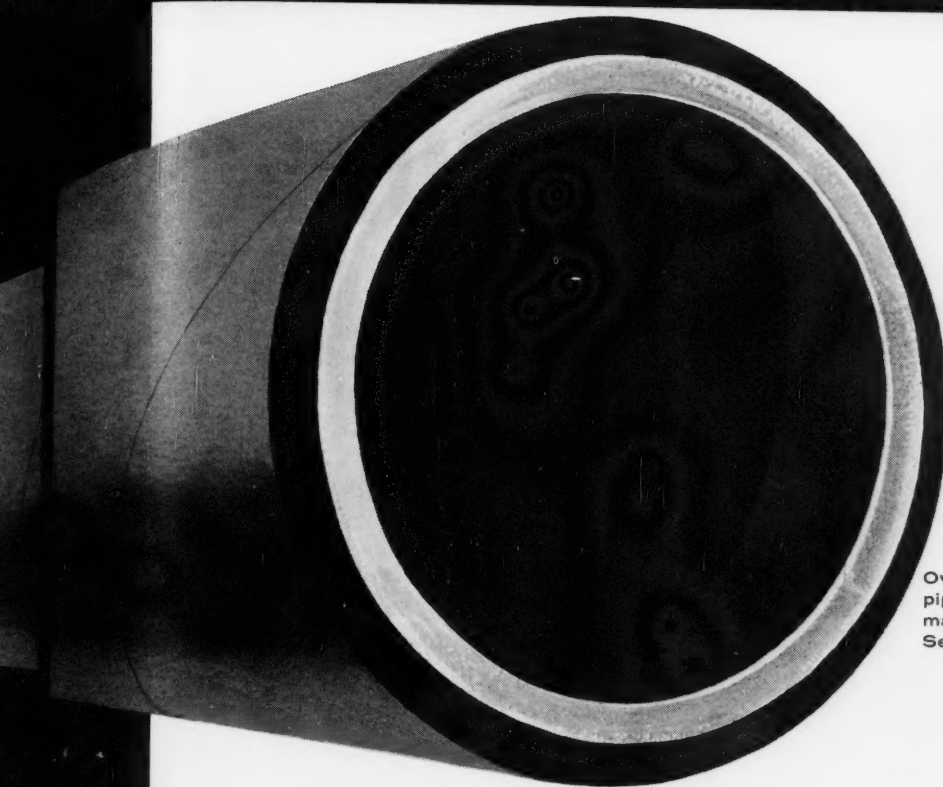
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There's a PLS plant strategically located to serve YOU!





Over 100,000 miles of protected pipe in 25 years... that's the unmatched experience of Pipe Line Service!

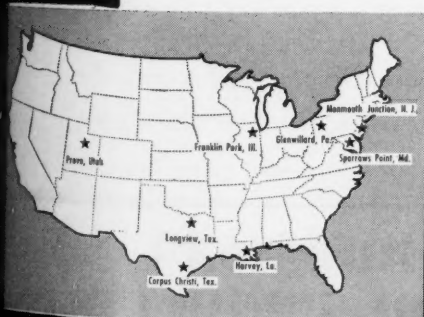
## *Experience that's measured in thousands of miles!*

Everywhere in the industries we serve, the value of *uniform* pipe protection is becoming more and more widely recognized. The difference between uniform protection and hit-or-miss field work can often mean the difference between future profit and loss.

And so the *experience* of the company that coats and wraps pipe... the ability to stick to high standards of uniformity... are factors that are being given an extra-careful look. After all, valves, pumps and other components are always accessible for inspection

or replacement. But, once pipe is buried, there's only one inspection possible—the *inspection of time!*

That's why Pipe Line Service makes no compromise with the quality of protection that results from *controlled* production—under roof and independent of the weather. That's why we've always pioneered in new processes... better machinery... closer inspection. For the finest in pipe protection—and for the maximum return on your investment—call in your nearest PLS representative!



Also Sales Offices at  
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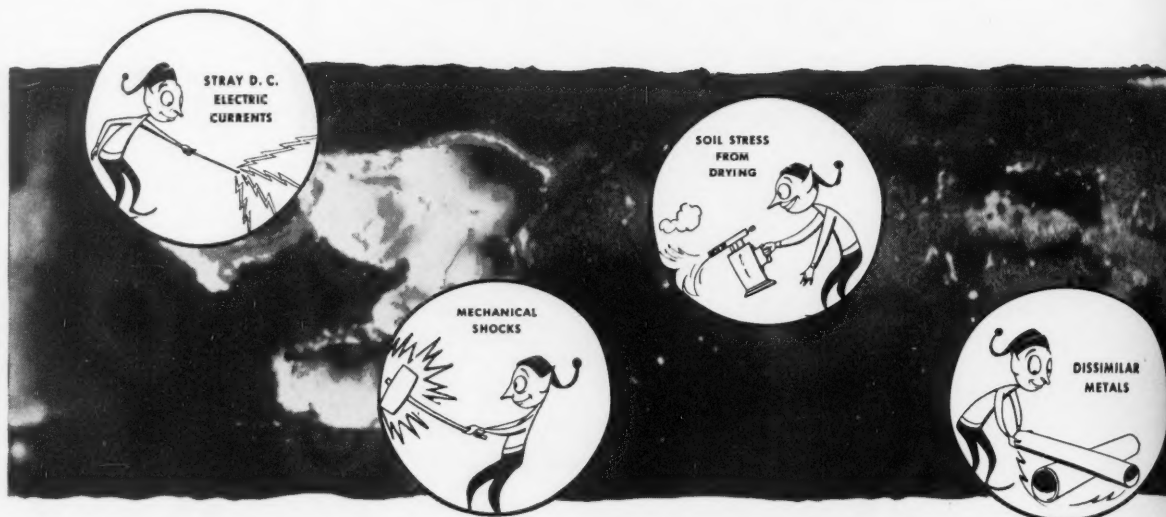


## *Pipe Line Service Corporation*

FRANKLIN PARK, ILLINOIS

*Quality pioneers  
in coating and wrapping pipe  
for a quarter century*

# 6 DRESSER PRODUCTS T THESE MAJOR CAUSES O



## ***Gas Men Seek Improved Insulating Methods ... Help Develop Dresser Insulating Products***

Whenever utility men get together, corrosion almost always heads the list for discussion—how to best protect their company's huge investment in underground piping. Satisfied that insulated pipe effectively resists corrosion, they are naturally interested in talking over improved insulating methods, new insulating applications.

Having pioneered the insulated pipe joint, over 50 years ago, Dresser can draw on a reservoir of experience in corrosion protection to better serve the industry. Working closely with gas engineers and superintendents, Dresser Corrosion Laboratories have, since that time, developed many effective methods of insulating against corrosion. These have resulted in today's wide variety of Dresser Insulating Products—each designed to meet a specific need in protecting pipe and pipe joints.\*

**For Complete Details on How You Can Get More Effective, Economical Corrosion Protection, Send for Dresser Corrosion Control Catalog**

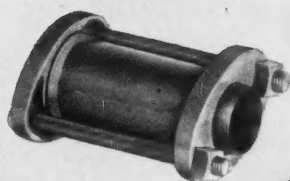
\*INSULOK and DRESSERTAPE are trade-marks of Dresser Mfg. Div.

**DRESSER® CORROSION  
CONTROL PRODUCTS**



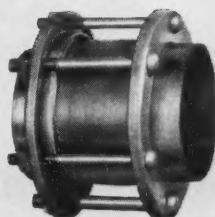
# TS TO HELP YOU FIGHT ES OF PIPE CORROSION!

SOIL ACIDS



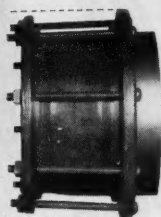
## INSULATING COUPLINGS STYLE 39

Basically the same design as the well-known Dresser Style 38 Coupling, the Style 39 has rubber insulating gaskets compounded to assure optimum insulation and long life. The tough, inert polyethylene skirt is immune to acids, alkalies, drip oils . . . will not swell.



## INSULATING-REDUCING COUPLINGS • STYLE 39-62

This combination insulating and reducing coupling eliminates the danger of corrosion from joining dissimilar metals. The insulating gasket is supplied as standard on the cast-iron pipe end. A polyethylene skirt separates and insulates the pipe ends.



## INSULOK \* ADAPTERS STYLE 90

This new insulating connector is made to order for setting gas meters and regulators—a virtually tamper-proof fitting which resists pull-out from the unusual strains often put on service line piping.

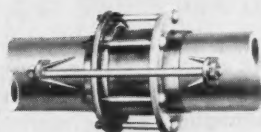


## INSULATING SERVICE LINE FITTINGS STYLE 90



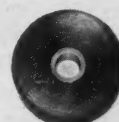
These small diameter insulating couplings and fittings provide fast joining of service piping up to 2", plus permanent corrosion protection. Both the nut and fitting body are insulated from the pipe.

## INSULATING JOINT HARNESSES



Used in conjunction with Dresser Insulating Couplings, at bends and other points of stress, these harnesses restrict pipe movement at the joint, while preventing "by passing" current flow through the lugs and harness bolts.

## DRESSERTAPE\*

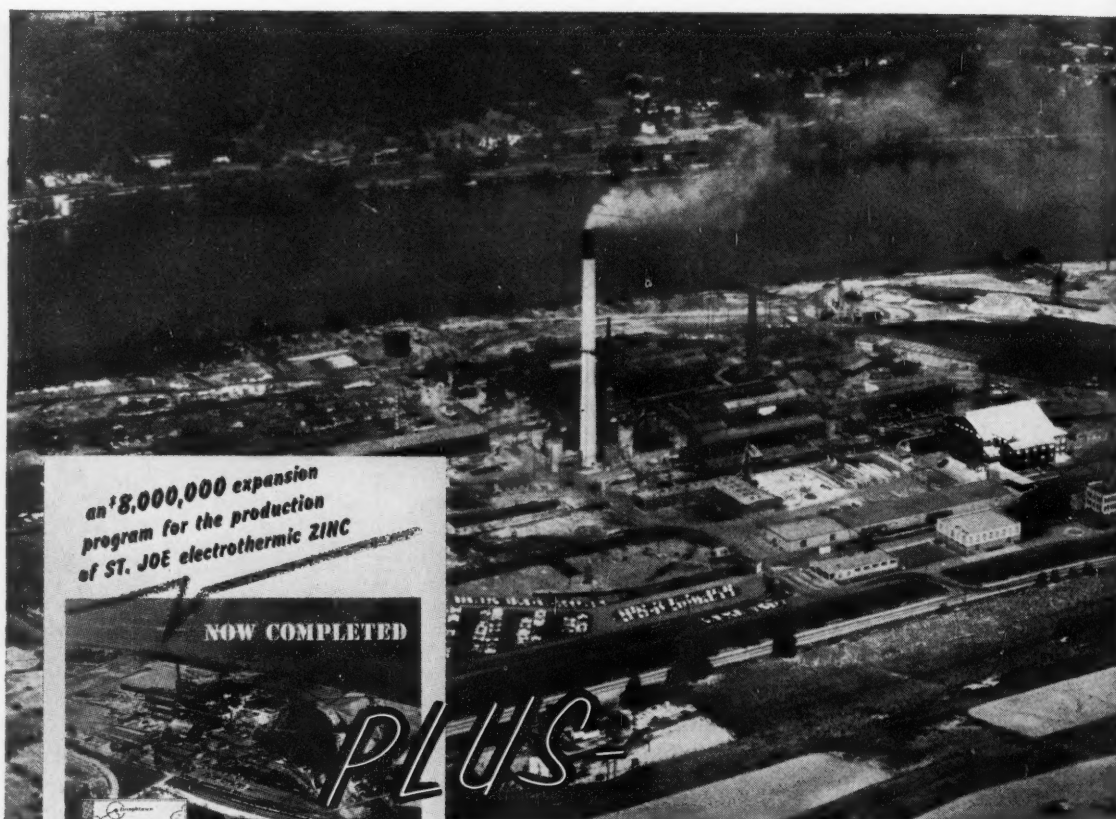


A high dielectric plastic pipe tape providing positive electrical insulation, while protecting underground pipe against salt water, soil chemicals, acids, alkalies and oil. Available in 10 and 20 mil thicknesses, all standard widths.

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an \$8,000,000 expansion  
program for the production  
of ST. JOE electrothermic ZINC

NOW COMPLETED

PLUS

\$20 MILLION

ST. JOSEPH LEAD COMPANY  
250 PARK AVENUE, NEW YORK 17, NEW YORK, ELdorado 5-3200

## for still more St. Joe Zinc

The advertisement shown above in miniature was published in the trade press in 1950. It announced that the processing capacity of our Josephstown smelter had been raised from about nine to sixteen thousand tons of zinc concentrate per month. At the then prevailing rate of zinc consumption, the expansion of plant and equipment, at a cost of \$8 million, was normal.

The current program is adapted to the changing picture in the market for zinc. Its aim is to increase the smelting capacity of zinc concentrates from the monthly intake of 16,000 to more than 25,000 tons.

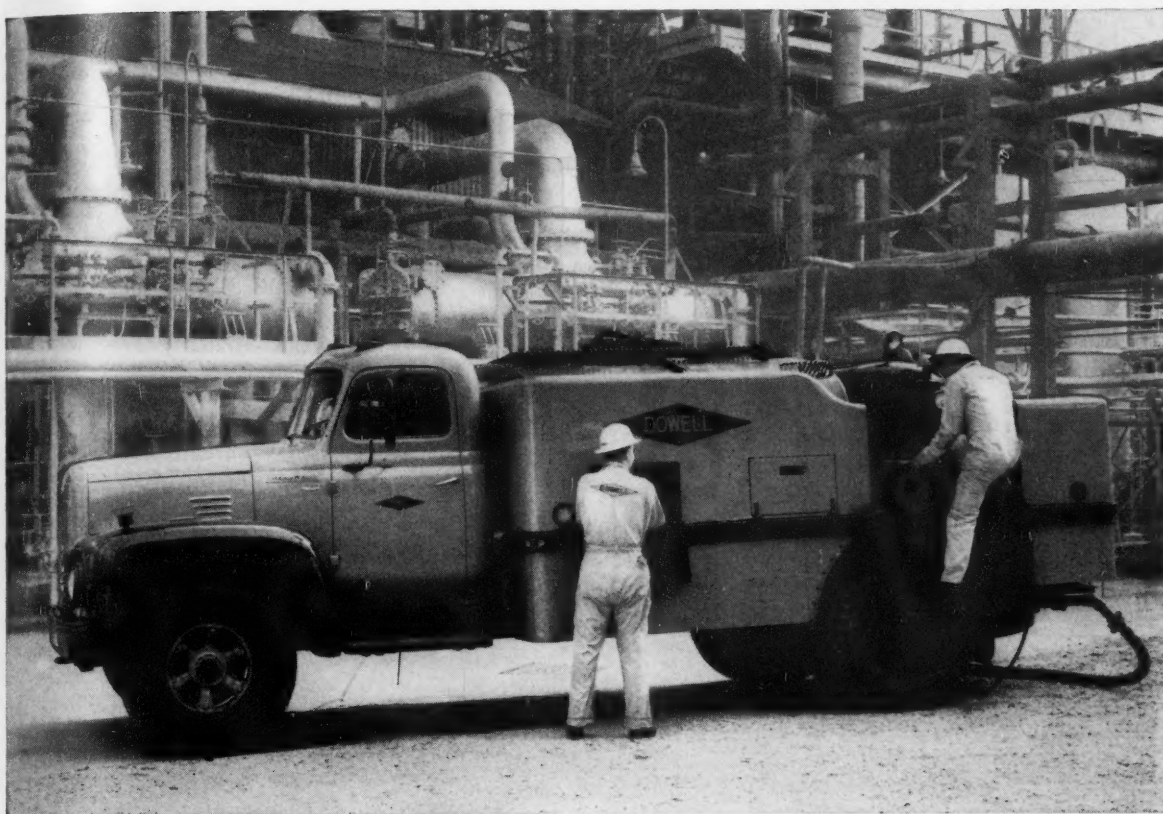
An important factor in the company's decision to

further expand the smelter's processing capacity has been the phenomenal growth of the continuous galvanizing process. Due to this unique in-line, one-pass operation, the galvanized product has all the properties of, and is as ductile as the base metal. It can be drawn, spun, stamped—the protective zinc coating will not crack, flake or peel off despite the severity of the forming operation. This, together with the fact that the product can be delivered in rolls for cutting into desired lengths by the consumer, has greatly enlarged the field of application for sheet and strip steel which has been rust-proofed with a coating of zinc—the protective metal.

ST. JOSEPH LEAD COMPANY  
250 PARK AVENUE, NEW YORK 17, N. Y.

HIGH GRADE  
INTERMEDIATE  
PRIME WESTERN

ST. JOE *electrothermic* ZINC



**Dowell's Special Tank Trucks**, equipped with proportioning and pumping equipment, bring solvents for chemical cleaning of industrial equipment to plant sites.

## Monel handles dilute HCl day-after-day in Dowell equipment-scrubbing units

When processors find it necessary to clean the interior surfaces of large industrial equipment of rust and scale, they often use the means provided by Dowell Incorporated. Dowell brings tank trucks to the plant site and pumps solvents through the equipment to dissolve and sweep away any deposits. The solvent usually has a dilute hydrochloric acid base; sometimes others are used. To prevent the equipment from corroding, the solvent contains specific inhibitors and is introduced under strict control of temperature and exposure time.

### Pumps posed difficulty

The centrifugal pumps used to circulate the acidic solvent posed a real problem to Dowell. Centrifugal force and high velocities stripped protective coatings from impellers and nullified the effect of inhibitors inside the pump. A need was indicated for parts of durable, corrosion-resisting metal.

Dowell's tests of many materials gave an answer . . .

### Monel® nickel-copper alloy

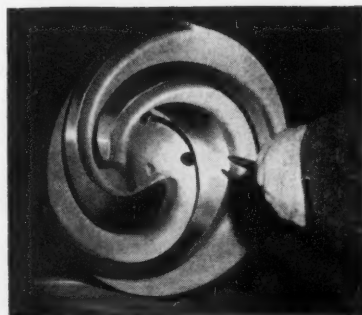
Monel alloy, with its inherent resistance to dilute hydrochloric acid, is used by Dowell for pump impellers, stuffing box seals and shaft sleeves as well as for certain storage tank accessories.

You, too, may find Monel nickel-copper alloy an answer to your difficulty. Get the facts. Ask for Bulletin T-29, "Resistance of Nickel, Monel and Other High Nickel Alloys to Corrosion by Hydrochloric Acid, Hydrogen Chloride and Chlorine." It's yours for the asking.

**The International Nickel Company, Inc.**  
67 Wall Street New York 5, N. Y.

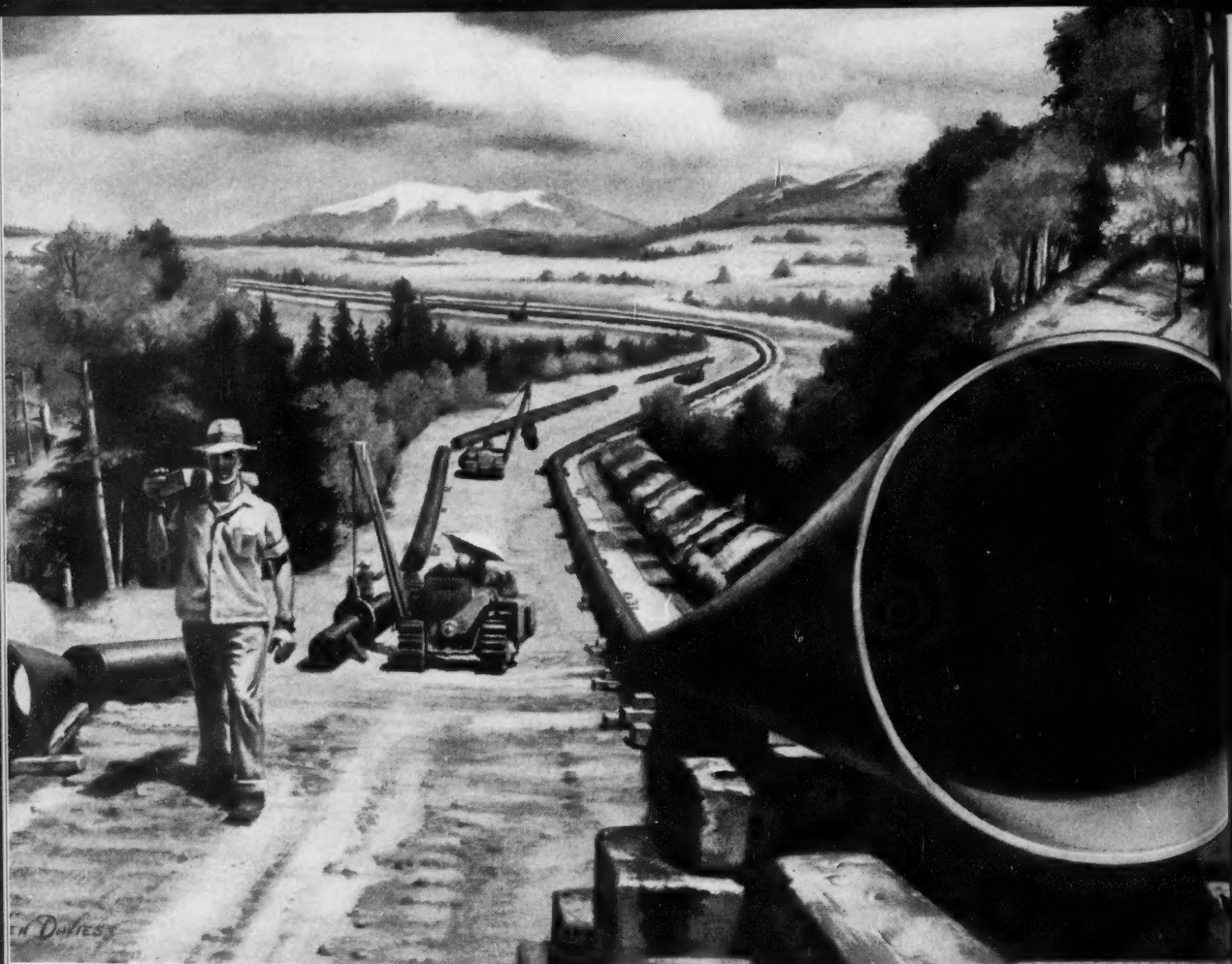


**Castings . . .** Sand, Centrifugal and Precision



**Heart of a "Chemical Brush"** . . . Monel nickel-copper alloy impellers like this are used in Dowell's pumps to introduce cleaning solvents into industrial equipment. They find that parts made of this alloy resist acidic and caustic solutions used in their operations.





Transcontinental pipelines are among the many places where Cathodic Protection and Anaconda Type CP Cable are used to check corrosion.

## Cable that helps make the pipeline a good neighbor

To make cathodic protection systems more economical and effective — to help pipeline and oil companies check costly corrosion, stop leaks, make pipelines good neighbors — Anaconda offers a special Type CP Cable that *lasts far longer* on the job than ordinary cable.

High-grade polyethylene insulation and tough Densheath\* (PVC) jacket offer high resistance to electroendosmosis†, as well as high resistance to oil, moisture, and most acids, alkalis and chemicals found in corrosive areas. And rugged Densheath withstands toughest abrasion, moisture,

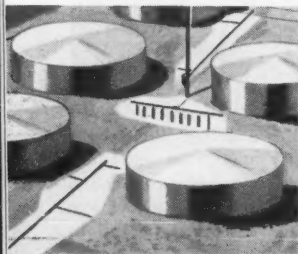
sunlight and weathering.

For special applications, a one-layer insulation and jacket construction of polyethylene is available.

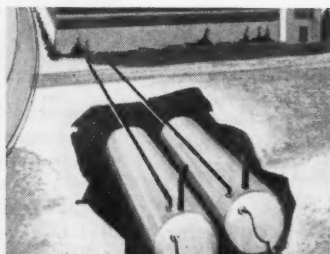
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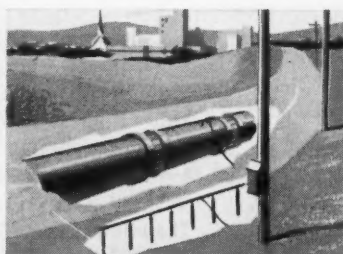
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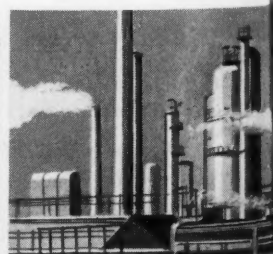
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## Topic of the Month

## Stress-Corrosion Cracking Test

By A. W. DANA\* and W. B. DELONG\*

## Introduction

IN ANY research program designed to study the stress corrosion cracking of metals, selection of test method is critical. The final method used depends largely on the aims of the program. Different procedures are required for study of basic mechanisms as compared to evaluation of materials or specific environments.

Recently a need developed within the Du Pont Company for study of the contribution of a specific environment, namely, thermal insulation, to the stress-corrosion cracking of austenitic stainless steel equipment. A unique experimental technique has been devised to meet requirements of this research study. It is felt that this test procedure may be of interest to others investigating stress-corrosion cracking of materials of construction.

Service experience has shown that water-soluble chlorides will be leached from certain insulating materials if these materials are wetted. Furthermore, concentration to high chloride contents can occur at the surfaces of hot operating equipment. These conditions can and do cause stress-corrosion cracking of austenitic stainless steels. Thus, any test method used to simulate such service conditions must incorporate the following:

1. A method for water leaching the water-soluble chlorides from the insulating material.
2. A means of concentration of the chloride-bearing solutions at the surface of the test specimen.
3. A simple procedure for varying specimen temperature.
4. A means for imposing applied stress.

To meet these requirements, an adaptation of the common U-bend specimen has been used.

## Test Apparatus

The experimental test set-up is depicted in Figure

1. The block of insulating material acts as a wick and transports distilled, deionized water from the dish to the specimen surface. If water-soluble chlorides are present, the water will leach them from the block and carry them to the specimen. Here, the chloride concentration of the water solution is increased by evaporation, in many cases to dryness. Specimen temperatures at the metal-insulation interface are controlled by using a resistance heater taped to the curved portion of the specimen and a transformer for varying power input. Little control can be exercised on the degree to which the chloride concentration in the water is increased at the specimen surface. However, this experimental condition is similar to

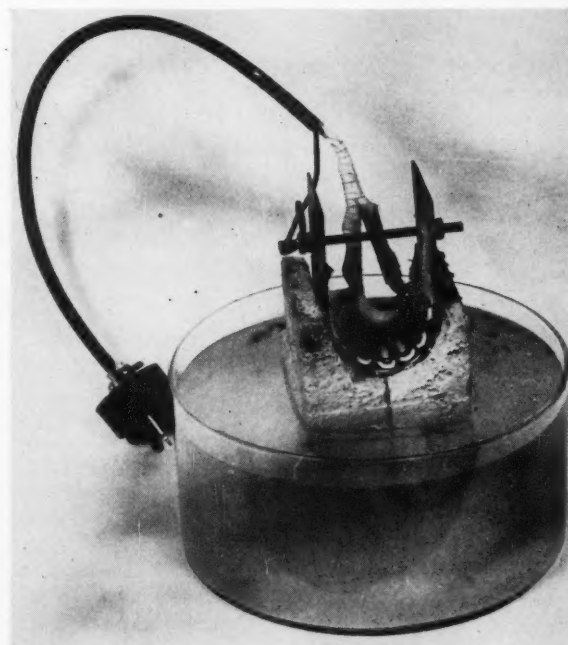


Figure 1—Experimental apparatus for study of environmental effects.

\*Engineering Research Laboratory, Engineering Department, E. I. du Pont de Nemours and Company, Wilmington, Delaware.

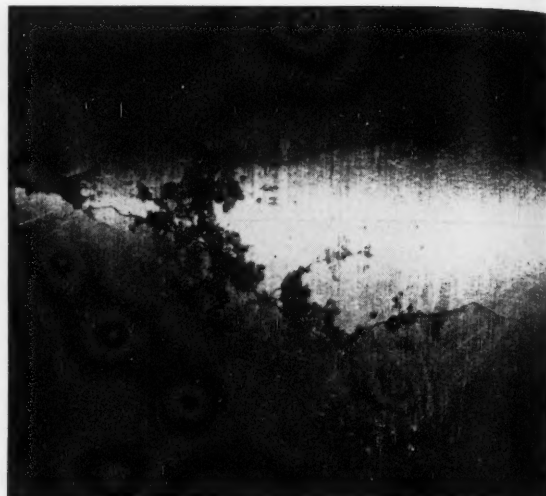
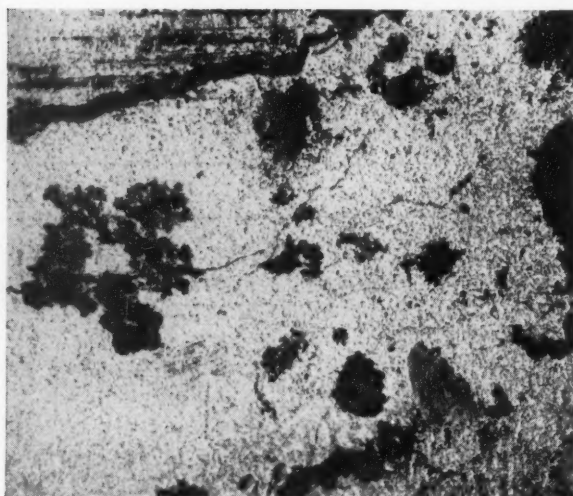


Figure 2—Typical stress-corrosion cracking of austenitic stainless steel on exposure to insulation. Left illustration shows cracking observed in service while right shot shows cracking observed in laboratory test. 6X.

that encountered in service and is considered to be an important feature of the test. Typical cracking from a service failure and a laboratory specimen are compared in Figure 2.

This test method also can be used to investigate other industrially important stress-corrosion cracking problems such as the cracking of austenitic stainless steel heat exchangers on exposure to chloride-bearing cooling water. Here an inert wicking material can be substituted for the insulation block and chlorides added to the water. Concentration of chlorides such

as occurs in crevices and recesses in the operating equipment is simulated at the specimen surface.

The described test method offers flexibility of test temperature, specimen composition, and environment. In addition, cost per test is low and multiple tests can be run in parallel. It has been used effectively for such purposes as the screening of potential crack-producing solutions. In this case, it is not necessary to decide in advance what concentrations should be used; the test conditions are such that the specimen surface is exposed to essentially all of the possible solution concentrations.

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## Part 2 of 2 Parts

# Corrosion Testing of Aluminum\*

## Part 2—Development of a Corrosion Inhibitor

By SUMNER B. TWISS\* and JACK D. GUTTENPLAN\*\*

(Continued from June, 1956 issue)

### Introduction

IN PART 1 of this article<sup>1</sup> it was pointed out that although the No. 100 aluminum brazing sheet suggested for use in automobile radiators corrodes very slowly in nearly neutral waters, serious attack nevertheless can occur under certain conditions. In the radiator, with its thin metal sections, corrosion in any amount might cause serious damage. For this reason, it was of importance to investigate corrosion inhibitors for use with coolants.

An accelerated laboratory corrosion test capable of reducing the time factor for testing clad aluminum is described in Part 1 of this paper. The use of this test for evaluating corrosion inhibitors is based on the following factors:

1. Increasing the velocity of movement, particularly to very high values on the order of 4700 feet/minute (12,000 rpm), accelerates the corrosion of clad aluminum in all of the natural and synthetic waters tested.

2. At high velocities, clad aluminum is rapidly attacked in waters of high alkalinity and relatively high chloride ion concentration. Royal Oak, Michigan, tap water is a good example of this type of water.

Inhibitors screened in this accelerated test which were found to exhibit good performance were given more extensive testing in the common radiator coolants. The combination inhibitor finally selected has been service tested with good results.

### Experimental

No. 100 aluminum brazing sheet test specimens were tested in Royal Oak tap water and various experimental radiator coolants made up with ethylene glycol (technical) and isopropyl alcohol (98 percent).

Materials tested as inhibitors were:

1. Sodium pyrophosphate.
2. Tartaric acid (practical).
3. Sodium borate.<sup>(1)</sup>
4. Sodium benzoate.
5. Sodium nitrite.
6. Disodium hydrogen phosphate.

### Abstract

An accelerated corrosion test was used to test a number of corrosion inhibitors at different concentrations to determine their effectiveness in preventing corrosion of No. 100 aluminum brazing sheet in Royal Oak tap water. Four inhibitors were found to be effective under conditions of static test, 1000 rpm and 12,000 rpm. These inhibitors were: soluble oil with or without trisodium phosphate, sodium dichromate, sodium silicate, and disodium hydrogen phosphate. Of these, all but the soluble oil are either non-compatible or might lose their effectiveness when used in standard antifreeze solutions. The corrosion inhibition of clad aluminum by soluble oil is less effective in waters of combined high pH and high chloride ion than it is in waters of high chloride alone. Addition of a buffer to the soluble oil to maintain the solution pH near 7.0 improves the effectiveness of this inhibitor in high pH solutions. The combination of soluble oil and buffer satisfactorily inhibits the corrosion of clad aluminum in 1:1 ratio ethylene glycol-water (pH 11) and isopropyl alcohol-water (pH 11) solutions, typical of the worst radiator solutions that might be encountered. The inhibition is somewhat less effective when the clad aluminum is coupled with brass.

6.4.2

7. Sodium silicate.
8. Inhibitor A (unidentified material containing Na and Cr)<sup>(1)</sup>
9. Soluble oil.<sup>(1)</sup>
10. Soluble oil—25 percent and trisodium phosphate (TSP)—25 percent in water emulsion.<sup>(1)</sup>
11. Sodium dichromate.<sup>(1)</sup>
12. Buffer consisting of 2 molar potassium dihydrogen phosphate—55 percent and 2 molar sodium hydroxide—45 percent.
13. Soluble oil—33 percent and buffer (as shown in 12)—67 percent.

The apparatus and method of running the high velocity corrosion test are described in detail in the first article of this series.<sup>1</sup> Each inhibitor was screened in Royal Oak tap water at two concentrations (3.0 and 0.03 percent) except commercial inhibitors, for which only the recommended service concentrations were used. Test disks of No. 100 aluminum brazing sheet were rotated in these inhibited solutions at 12,000 rpm. A temperature of 180 F was maintained to simulate the approximate average of summer and winter operating temperatures of an automobile radiator.

Effectiveness of the inhibitor was based both upon visual observation and weight loss measurement.

\* Submitted for publication January 24, 1955. A paper presented at the Eleventh Annual Conference, National Association of Corrosion Engineers, Chicago, Illinois, March 7-11, 1955.

\*\* Assistant chief engineer of the Engineering Research Section of Chrysler Corporation, Detroit, Michigan.

(1) Project engineer in corrosion and electroplating research of Chrysler Corporation, Detroit, Michigan.

(2) Recommended as commercial inhibitors for brass radiators.



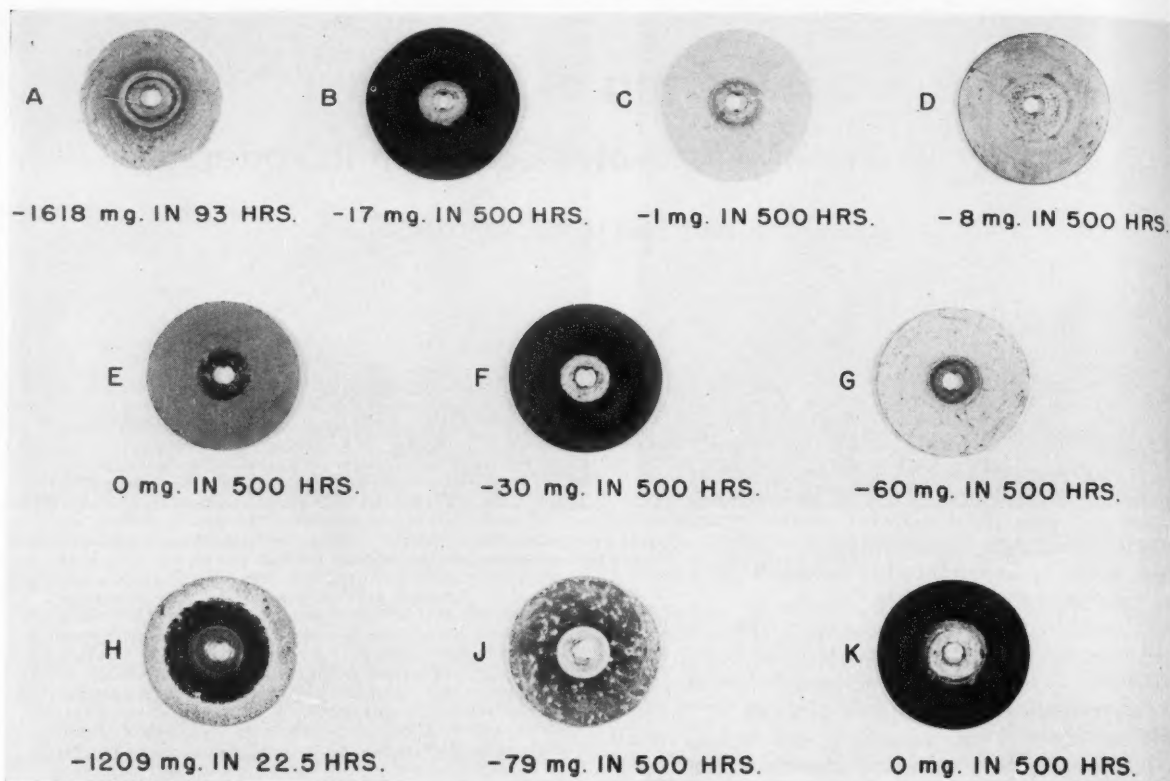


Figure 1—Test disks illustrating effect of inhibitors (X7272 alloy side shown). Disks A through E—Attack in Royal Oak tap water (ROTW); A—Uninhibited; B—0.03 percent disodium hydrogen phosphate; C—3.0 percent sodium silicate; D—3.0 percent soluble oil plus TSP; E—0.625 percent sodium dichromate; F—0.03 percent disodium hydrogen phosphate in (1:1) ROTW—isopropyl alcohol; G—0.625 percent sodium dichromate in (1:1) ROTW—ethylene glycol; H—Uninhibited ROTW with 522 ppm Cl and pH 11.0; J—1.0 percent soluble oil added to H; K—1.0 percent soluble oil plus 0.8 percent buffer added to H.

Failure as an effective inhibitor was fixed at either severe pitting of the disk or a weight loss of 50 mg (approximately 1 percent of the total weight). The successful inhibitors were tested for 500 hours and the weight loss at the end of this period used to indicate relative effectiveness.

### Results and Discussion

#### Screening Tests

Results of high velocity screening tests on possible inhibitors for No. 100 aluminum brazing sheet are given in Table 1. A disk rotated in uninhibited Royal Oak tap water was eroded to the extent of 1618 mg in 93 hours (Figure 1, disk A), losing 50 mg in approximately 35 hours. With this value as a base, in Table 1, any substance falling below it is a promoter of corrosion. Sodium pyrophosphate (3 percent), sodium borate (0.1 percent), and tartaric acid (3 percent) can be considered to fall in this class. In the presence of the first two materials, the disks were attacked at the edge, with the cladding gradually being eaten away. A corrosion-erosion type of attack of the base metal then occurred, starting at the edge and working inward—actually reducing the diameters of the disks. In the presence of tartaric acid, corrosion appeared to be general over the entire surface of the disk. Sodium pyrophosphate and tartaric acid, each tested at a lower concentration (0.03 percent), reduced the attack somewhat; however,

TABLE 1—Preliminary Screening of Inhibitors<sup>1</sup>

| Successful Inhibitors   | Weight Loss in 500 Hours        |
|---|---------------------------------|
| Sodium dichromate, 0.625 percent <sup>2</sup> .....                 | 0 mg                            |
| Sodium silicate, 3.0 percent.....                                   | 1                               |
| Inhibitor A, 0.03 percent.....                                      | 2                               |
| Inhibitor A, 3.0 percent <sup>2</sup> .....                         | 2                               |
| Soluble oil, 0.625 percent <sup>2</sup> .....                       | 3                               |
| Soluble oil and trisodium phosphate, 3.0 percent <sup>2</sup> ..... | 8                               |
| Disodium hydrogen phosphate, 0.03 percent.....                      | 17                              |
| Unsuccessful Inhibitors   | Time to Failure (Loss of 50 mg) |
| Sodium benzoate, 3.0 percent.....                                   | 265 hours <sup>3</sup>          |
| Sodium silicate, 0.03 percent.....                                  | 240 hours <sup>3</sup>          |
| Sodium nitrite, 0.03 percent.....                                   | 200 hours <sup>3</sup>          |
| Tartaric acid, 0.03 percent.....                                    | 175                             |
| Disodium hydrogen phosphate, 3.0 percent.....                       | 105                             |
| Sodium nitrite, 3.0 percent.....                                    | 80                              |
| Sodium pyrophosphate, 0.03 percent.....                             | 60                              |
| Sodium benzoate, 0.3 percent.....                                   | 35                              |
| No inhibitor.....   | 35                              |
| Sodium borate, 0.1 percent <sup>2</sup> .....                       | 22                              |
| Tartaric acid, 3.0 percent.....                                     | 5                               |
| Sodium pyrophosphate, 3.0 percent.....                              | 3                               |

<sup>1</sup> Test solution—Royal Oak tap water; Velocity—12,000 rpm; Temperature—180 F.

<sup>2</sup> Commercial inhibitor for brass radiators—recommended concentration.

<sup>3</sup> Failed first by pitting.

TABLE 2—Effect of Velocity on Protection by Selected Inhibitors<sup>1</sup>

| Inhibitor                                      | WEIGHT LOSS   |              |        |
|--|---------------|--------------|--------|
|  | At 12,000 rpm | At 1,000 rpm | Static |
| Sodium silicate, 3.0 percent.....              | 1 mg          | 1 mg         | 1 mg   |
| Sodium dichromate, 0.625 percent.....          | 0             | 0            | 0      |
| Soluble oil and TSP, 3.0 percent.....          | 8             | 0            | 0      |
| Disodium hydrogen phosphate, 0.03 percent..... | 17            | 14           | 9      |

<sup>1</sup> Test Solution—Royal Oak tap water; Length of Test—500 hours; Temperature—180 F.

erosion corrosion still occurred and the disks failed in 60 and 175 hours, respectively, by weight loss.

Sodium nitrite at 3 percent concentration had little inhibiting effect; the test disk suffered corrosion at the edge and failed in 80 hours. At a lower concentration of 0.03 percent, sodium nitrite reduced the weight loss considerably although localized pitting occurred. This disk failed by weight loss in 200 hours.

Change in sodium benzoate concentration had the opposite effect to that found with sodium nitrite. At the higher concentration, 3 percent, a fairly low weight loss occurred. The disk failed in 265 hours, however, because of localized pitting. At a lower concentration of 0.3 percent, erosion occurred and the disk failed in 35 hours.

Disks rotated in 3.0 percent disodium hydrogen phosphate and 0.03 percent sodium silicate both failed—the former at 105 hours by weight loss and the latter at 240 hours by localized pitting. However, when these materials were retested at 0.03 percent and 3.0 percent, respectively, they proved to be effective inhibitors in Royal Oak tap water. Disodium hydrogen phosphate formed a very uniform dark black film, and sodium silicate formed a rougher white film as shown in Figure 1, disks B and C, respectively. Both films appeared to be quite protective.

Two other classes of materials proved effective. These were soluble oils (with and without trisodium phosphate) and sodium dichromate (including Inhibitor A). Both types formed thin, iridescent films on the zinc-aluminum alloy surface of the brazing sheet as shown in Figure 1, disks D and E, respectively. The weight losses and condition of the disks were satisfactory for all four of these inhibitors.

#### Further Testing of Effective Materials

Having found four materials capable of inhibiting the corrosion of No. 100 aluminum brazing sheet in Royal Oak tap water under accelerated conditions, the following questions arose:

1. Would these materials inhibit corrosion under velocity conditions similar to those found in the radiator?
2. Would these materials be effective in other coolants and antifreezes?

To answer the first question, disks were tested in Royal Oak tap water solutions containing soluble oil—TSP, sodium dichromate, sodium silicate, and disodium hydrogen phosphate at 1000 rpm or 392 feet/minute (a peripheral velocity corresponding to

TABLE 3—Protection by Inhibitors in Antifreeze Solutions<sup>1</sup>

| Inhibitor                                      | WEIGHT LOSS |                           |                             |
|--|-------------|---------------------------|-----------------------------|
|  | Water Alone | Water and Ethylene Glycol | Water and Isopropyl Alcohol |
| Sodium silicate, 3.0 percent.....              | 1 mg        | 0 mg                      | 4 mg <sup>2</sup>           |
| Sodium dichromate, 0.625 percent....           | 0           | 60                        | 0                           |
| Soluble oil and TSP, 3.0 percent....           | 8           | 3                         | 0                           |
| Disodium hydrogen phosphate, 0.03 percent..... | 17          | 0                         | 30                          |

<sup>1</sup> Test Solution—Royal Oak tap water; Length of Test—500 hours; Velocity—12,000 rpm; Temperature—180 F.

<sup>2</sup> Inhibitor not compatible with alcohol solution.

the maximum linear flow in the tubes of a Plymouth automobile radiator at 3300 rpm engine speed). They were tested also under static conditions, in addition to the accelerated test at 12,000 rpm. The concentration of inhibitor found most effective in the screening test was used. Results of these tests are given in Table 2. In all cases the inhibitors were at least as effective at the lower speed and at static as they were under the accelerated conditions.

To answer the second question, disks were tested at 12,000 rpm in inhibited solutions of Royal Oak tap water—isopropyl alcohol and Royal Oak tap water—ethylene glycol (representing alcohol and permanent type antifreezes, respectively). Results are given for each of the four effective inhibitors in Table 3.

As discussed in Part 1 of this series, the No. 100 brazing sheet was not corroded by Royal Oak tap water—isopropyl alcohol solutions at any velocity up to and including 12,000 rpm. From these results it is probable that corrosion inhibition will not be required for clad aluminum in this particular type of antifreeze. The only value of tests run in the alcohol solution, therefore, is to determine the compatibility of the inhibitor with the solution and to indicate whether the inhibitor might cause any detrimental action. In other words, since the alcohol itself appears to inhibit corrosion, the accelerated test would not differentiate between a good or a poor inhibitor. However, a promoter of corrosion in isopropyl alcohol solution would be detected. Soluble oil—TSP and sodium dichromate were compatible with Royal Oak tap water—isopropyl alcohol solutions, and had no adverse effect. Disodium hydrogen phosphate apparently promotes pitting of the clad aluminum in alcohol solution (Figure 1, disk F). Sodium silicate is not compatible, separating out as a flocculent precipitate.

In Royal Oak tap water—ethylene glycol solutions, soluble oil—TSP, sodium silicate, and disodium hydrogen phosphate remained effective. Sodium dichromate, however, did not prevent pitting of the disk (Figure 1, disk G). The relatively high weight

TABLE 4—Effect of Water Composition on Inhibitor Protection in Antifreeze Solutions<sup>1</sup>

| Water Composition  | WEIGHT LOSS |                           |                             |
|--|-------------|---------------------------|-----------------------------|
|  | Water Alone | Water and Ethylene Glycol | Water and Isopropyl Alcohol |
| Royal Oak tap water.....   | 8 mg        | 3 mg                      | 0 mg                        |
| Royal Oak tap water (522 ppm Cl <sup>-</sup> )                                     | 10          | 21                        | 3                           |
| Royal Oak tap water (522 ppm Cl <sup>-</sup> and 500 ppm NaHCO <sub>3</sub> )..... | 52          | ....                      | ....                        |

<sup>1</sup> Velocity—12,000 rpm; Temperature—180 F; Length of Test—500 hours Inhibitor—3 percent Soluble Oil and TSP.

TABLE 5—Effect of pH on Inhibitor Protection in High Chloride Water<sup>1</sup>

| Inhibitor   | WEIGHT LOSS |                      |                      |
|---|-------------|----------------------|----------------------|
|   | pH 6        | pH 8                 | pH 11                |
| None.....   | 48 mg       | 1311 mg <sup>2</sup> | 1209 mg <sup>3</sup> |
| 1.0 percent soluble oil (alone).....                | 3           | 18                   | 78                   |
| 1.0 percent soluble oil and 0.8 percent buffer..... | 3           | 7                    | 0                    |

<sup>1</sup> Test Solution—Royal Oak tap water (522 ppm Cl<sup>-</sup>); Velocity—12,000 rpm; Length of Test—500 hours; Temperature—180 F.

<sup>2</sup> 122 hours.

<sup>3</sup> 22.5 hours.

loss in this medium indicated that sodium dichromate was not effective. Sodium dichromate was also considered a poor risk in the glycol solution because of its strong oxidizing nature. Sodium silicate caused excessive foaming in all three coolants.

Of the four effective materials tested, all but the soluble oil—TSP inhibitor were either non-compatible or considered harmful for use in standard anti-freeze solutions.

Testing of the soluble oil—TSP inhibitor in Royal Oak tap water with 522 ppm of chloride ion<sup>(2)</sup> (as compared to a normal 63 ppm) caused no additional corrosion (Table 4). However, this water in combination with isopropyl alcohol and ethylene glycol when inhibited did cause more pitting and slightly higher weight losses than occurred without the addition of the chloride ion. When 500 ppm of sodium bicarbonate were added to Royal Oak tap water in addition to the high chloride, the soluble oil—TSP inhibitor reached the borderline of effectiveness.

### Experimental Soluble Oil—Buffer Combination Inhibitor

#### Selection and Testing

From the preceding observations it became apparent that the effectiveness of a soluble oil inhibitor for No. 100 brazing sheet was considerably reduced in the presence of high chloride and high alkalinity. To test this conclusion further, the pH of Royal Oak tap water was adjusted to 6.0 with hydrochloric acid and to 11.0 with sodium hydroxide, maintaining the chloride ion concentration constant at 522 ppm (see Part 1 of this series, Figure 7 for graphic results with the uninhibited waters). As shown in Table 5, 1.0 percent of soluble oil alone was very effective at pH 6.0, satisfactory at the slightly alkaline pH of 8.0, but not effective at pH 11.0. Although there was a considerable reduction in attack from the results at pH 11.0 when uninhibited (disk H, Figure 1), localized pitting still occurred with the soluble oil present (disk J, Figure 1).

From these experiments it was concluded that addition of a buffer to the solution to maintain the pH close to neutral would considerably enhance the effectiveness of the soluble oil inhibitor. Accordingly, a buffer containing 55 percent of 2 molar potassium dihydrogen phosphate plus 45 percent of 2 molar sodium hydroxide was selected. A combination inhibitor that would give 0.8 percent of buffer solids in the final solution (sufficient to maintain the solution pH at 7.5) plus 1.0 percent soluble oil was made up. This experimental inhibitor proved to be effective at 12,000 rpm in Royal Oak tap water containing 522 ppm chloride and adjusted before addition of the buffer to the three pH values of 6.0, 8.0, and 11.0 (Table 5). With the original pH 11.0 water, the weight loss was now reduced to a low value and no pitting occurred (disk K, Figure 1). Similarly, weight loss in the pH 8 water was reduced slightly and weight loss in pH 6 water remained constant. The characteristic black film caused by the acid phosphate (previously found

for disodium hydrogen phosphate) appeared on the disks in these tests.

Tests were run at 12,000 rpm in Royal Oak tap water with 522 ppm chloride ion and pH adjusted to 11.0 to determine the optimum concentration of buffer. As shown in Table 6, the original concentration used, 0.8 percent buffer, appears to be more effective than either 0.4 percent or 3.2 percent. It should be noted that the buffer by itself at low concentrations is an effective inhibitor for aluminum (as previously found for disodium hydrogen phosphate in Royal Oak tap water).

To test the effectiveness of the experimental soluble oil—buffer inhibitor under conditions of velocity more closely approximating those found in the radiator, tests were run at 1000 rpm and at static in addition to the accelerated velocity of 12,000 rpm in water alone and in ethylene glycol and isopropyl alcohol solutions. The water used in these tests was Royal Oak tap water with 522 ppm chloride ion and pH adjusted to 11.0. Results are listed in Table 7. In all three types of coolants and at all three velocities the experimental inhibitor remained effective.

It is of interest to point out here that with the inhibited high pH water, for the first time, an apparent reversal occurred in the normal effect of velocity on the corrosion of No. 100 brazing sheet. In this instance, the static and 1000 rpm conditions were apparently slightly more corrosive than the high velocity (12,000 rpm) conditions as indicated by

TABLE 6—Determination of Optimum Buffer Concentration<sup>1</sup>

| Concentration of Buffer | 0.4 Percent | 0.8 Percent | 3.2 Percent |
|-------------------------|-------------|-------------|-------------|
| Weight loss.....        | 8 mg        | 5 mg        | 32 mg       |

<sup>1</sup> Test Solution—Royal Oak tap water (522 ppm Cl<sup>-</sup>, pH 11); Velocity—12,000 rpm; Temperature—180 F; Length of Test—500 hours; Inhibitor—Buffer (alone).

TABLE 7—Performance of Soluble Oil-Buffer Inhibitor in Antifreeze Solutions

|                                       | WEIGHT LOSS          |                    |        |
|---------------------------------------|----------------------|--------------------|--------|
|                                       | 12,000 rpm.          | 1,000 rpm          | Static |
| <b>Water Alone:</b>                   |                      |                    |        |
| Uninhibited.....                      | 1209 mg <sup>2</sup> | 34 mg              | 5 mg   |
| Inhibited.....                        | 0                    | 17                 | 18     |
| <b>Water—Ethylene Glycol (1-1):</b>   |                      |                    |        |
| Uninhibited.....                      | 646 mg <sup>3</sup>  | 88 mg <sup>4</sup> | 10 mg  |
| Inhibited.....                        | 0                    | 0                  | 0      |
| <b>Water—Isopropyl Alcohol (1-1):</b> |                      |                    |        |
| Uninhibited.....                      | 0 mg                 | 0 mg               | 0 mg   |
| Inhibited.....                        | 0                    | 0                  | 0      |

<sup>1</sup> Test Solution—Royal Oak tap water (522 ppm Cl<sup>-</sup>, pH 11); Length of Test—500 hours; Temperature—180 F; Inhibitor—1 percent Soluble Oil, 0.8 percent Buffer.

<sup>2</sup> 22.5 hours.

<sup>3</sup> 290 hours.

<sup>4</sup> 483 hours.

TABLE 8—Performance of Soluble Oil-Buffer Inhibitor in Cycle Test<sup>1</sup>

|  | Weight Loss |
|--|-------------|
| <b>Cycle Test:</b>                             |             |
| No inhibitor.....                              | 36 mg       |
| Inhibited.....                                 | 12          |
| <b>Continuous Test at 1,000 rpm and 180 F:</b> |             |
| No inhibitor.....                              | 34 mg       |
| Inhibited.....                                 | 17          |

<sup>1</sup> Test Solution—Royal Oak tap water (522 ppm Cl<sup>-</sup>, pH 11); Cycle—7 hours on at 1,000 rpm and 180 F; 16 hours off at Static and Room Temperature; Length of Test—500 hours; Inhibitor—1 percent Soluble oil, 0.8 percent Buffer.

(2) A representative high chloride content for the natural waters of the United States.



weight loss, although no attack occurred on the exposed surfaces under any of the three conditions. A careful examination of the disks indicated that attack at the lower velocities was concentrated at crevices and recesses beneath the insulating washer, pointing to a concentration cell type corrosion and resulting from differences in concentration of the inhibitor. This type of attack did not occur to any great extent at 12,000 rpm, probably as a result of the effect of the turbulence and pressure resulting from the high velocities in increasing the micro-penetrating power of the inhibitor.

A more accurate picture of the action occurring in a radiator might be determined by means of an on-off cycling test. Disks were cycled in inhibited and uninhibited Royal Oak tap water with 522 ppm chloride ion and pH adjusted to 11.0 for 16 hours at static and room temperature followed by 7 hours at 1000 rpm and 180 F. In these tests, use of the experimental inhibitor lowered the weight loss in 500 hours by over 66 percent (Table 8).

### Effect of Galvanic Couple

Inasmuch as it is possible that brass outlet cocks and filler caps might be used in conjunction with an aluminum radiator, it appeared to be of interest to study the No. 100 brazing sheet—brass couple. For this purpose 70-30 brass was used, the couple being effected by placing a 1 inch diameter brass disk on top of a 1.5 inch diameter clad aluminum disk (with the X7272 zinc-aluminum alloy cladding in contact with the brass). The coolant used was Royal Oak tap water with 522 ppm chloride ion and pH adjusted to 11.0. Results indicate that the soluble oil—buffer experimental inhibitor is just within the range of effectiveness for inhibiting the clad aluminum disk in the couple. Pitting of the clad aluminum occurred at the circle of contact of the two metals with the solution, and a weight loss of 45 mg was recorded in 500 hours at the accelerated velocity of 12,000 rpm.

### Reference

1. Sumner B. Twiss and Jack D. Guttenplan. Corrosion Testing of Aluminum (Part I—High Velocity Test Method in Aqueous Solutions). *Corrosion*, 12, 263t (1956) June.

### DISCUSSIONS

#### Comment by David G. Vandenburg, Aluminum Research Laboratories, New Kensington, Pa:

The authors have presented interesting findings on the corrosion resistance of an aluminum brazing sheet designed for application in automotive radiators. The accelerated corrosion testing technique which they developed is unique. The employment of this accelerated procedure permitted, in a minimum of time, an evaluation of the behavior of the aluminum to various aqueous solutions for coolants in automotive engines.

For some time the Aluminum Company of America has been working on the development of brazed aluminum radiators including corrosion testing. It may be noted, for the record, that the designation of the No. XA30 brazing sheet has recently been

changed to No. 100 brazing sheet.

In this discussion the authors indicated that their test specimens of aluminum disks (0.051 inch ga) were tested as mill-fabricated or as-rolled brazing sheet and the zinc-aluminum cladding surface was faced upwards in the solution. Comparison of this specimen with a brazed aluminum radiator tube reveals several variations which might influence the performance.

In the fabrication of a brazed aluminum radiator the No. 100 brazing sheet in gages of about 0.010 inch are formed into tubes with the zinc-aluminum cladding (15 percent thickness) on the inside surfaces. The radiator after assembly is joined in a dip-brazing operation wherein the silicon-aluminum alloy (10 percent thickness) on the outside surface is melted and forms the fillets. At the high brazing temperature (about 1120 F) some zinc from the cladding diffuses into the 3003 core. The result is that the zinc-aluminum cladding is less anodic to the core after brazing. Measurements of solution potential indicate the concentration of zinc in the surface layers has been reduced from 2.5 percent to about 1 percent.

Although the aluminum disk specimens were insulated from the dissimilar metal of the rotating shaft in these tests, appreciable galvanic effects might have occurred between the zinc-aluminum and silicon-aluminum surfaces in some environments. It would be expected that the zinc-aluminum cladding would tend to protect the brazing side in most aqueous solutions. In a radiator tube only the much smaller area of brazing alloy in the tube seam would be exposed to the cladding in the coolant.

To determine the significance of these variations comparative tests with modified specimens might be considered. The use of Alclad 3003 specimens (3003 clad on both sides with X7272) might provide a better simulation with radiator tubes.

A part of this investigation was described in which the effect of pH was determined by employing solutions having initial values of pH adjusted from 6 to 11. In this connection two questions have come to mind: Were the pH values of the solutions also measured at the completion of the tests so as to observe any changes? What is the highest pH value encountered in natural water or coolant solutions for radiators in service?

You indicated that some tests were conducted with specimens of aluminum disks coupled to brass and mentioned that these tests were to simulate some early experimental aluminum radiator which for convenience had brass filler necks. As is well known, in most electrolytes aluminum will be anodic and will, therefore, be sacrificed in protecting brass in a galvanic couple. For this reason it would be well to clarify again that the use of brass fittings in contact with the coolant should be avoided in the design of an aluminum radiator.

#### Reply by Sumner B. Twiss and Jack D. Guttenplan:

The fact that the zinc-aluminum cladding partially diffuses into the 3S core was known early in this research. At that time, however, no suitable specimens

of brazed sheet could be obtained for use in the accelerated tests. Service results have since confirmed the validity of information obtained on the XA-30 (or No. 100) sheet in an unbrazed condition.

Because some silicon-aluminum cladding is exposed in the radiator to coolant at tube seams and at seams where the headers enter into the tanks, it was thought advisable to expose both surfaces in the accelerated tests. Galvanic effects such as those described by you should tend to accelerate the dissolution of the zinc-aluminum cladding. Since it was desired to obtain the most severe conditions that might be encountered, both surfaces were exposed. However, results of tests using a specimen clad on both sides with the zinc-aluminum alloy should prove interesting.

pH values were taken upon completion of the tests referred to. In general, these tests were run to determine the effectiveness of the soluble oil-buffer inhibitor. The final pH was in the range of 7.1 to 8.0 because of the action of the buffer. Where the original pH was adjusted to 6.0 and 8.0 without addition of buffer, final pH values in general depended on the amount of aluminum corrosion; the greater the corrosion, the higher the final pH, with values ranging up to approximately 9.0. Solutions with an original pH of 11.0, in the absence of buffer, tended to drop in pH value to approximately 10.0. From a survey taken on June 2, 1952, of tap water analyses in U. S. cities of approximately 100,000 population or over, the highest pH value encountered was 10.4. Values of 10.0 or more were recorded in seven distinct sections of the country.

We believe you were misinformed on the reason for running tests on aluminum-brass couples. Brass filler necks were not used in any of these radiators, even the early ones. As stated in the paper, brass outlet cocks and filler caps were used at one time, but no accelerated galvanic corrosion was apparent in radiator tests. Aluminum-brass couples were run in the high speed test to discover how serious galvanic corrosion might become under severe operating conditions. We agree with you that brass fittings should be avoided.

#### Comment By George E. Best, Baltimore, Md.:

With respect to the test with dichromate in glycol solution, it is pertinent both that dichromate forms an acidic solution and that the tests were carried out in glassware unshielded from light.

Hexavalent chromium oxidizes more readily in acidic solutions, and its oxidizing power increases with increasing acidity by virtue of the fact that this reaction is acid-consuming. Accordingly it is possible a more favorable result would be obtained from us-

ing chromate in place of dichromate, the former being mildly alkaline and often requiring no other additive to adjust to the range of pH 7 to 9.5 which in many instances is optimum for corrosion inhibition. Supplementing with an appropriate buffer may sometimes be advantageous.

The fact of light catalyzing oxidation of organic material is widely utilized in various aspects of the photographic industry, (e.g., in photoengraving.) Here the primary purpose is not to achieve oxidation, but rather the attendant reduction of chromium. The importance of light shielding for the stability of chromate in methanol solutions has been mentioned in *Corrosion*, 10, 217 (1954) July.

Should reaction occur between glycol and hexavalent chromium, it is erroneous to consider that a condition of increasing acidity caused by organic acids would result. With either chromate or dichromate the amount of alkali released, (i.e., sodium ions from  $\text{Na}_2\text{CrO}_4$  or  $\text{Na}_2\text{Cr}_2\text{O}_7 \cdot 2\text{H}_2\text{O}$ ) would more than neutralize any organic acids formed and by actual test it can be confirmed that the pH rises rather than falls.

My comments regarding glycol oxidation refer strictly to reaction with hexavalent chromium, and do not apply to the gradual development of acidity from aeration and attendant oxidation of glycol antifreeze solutions in service.

#### Reply by Sumner B. Twiss and Jack D. Guttenplan:

From your comments on the use of sodium chromate or dichromate to inhibit glycol antifreezes, it would certainly appear that this type of inhibitor should have no adverse effect on increasing the amount of acidic products present in the antifreeze after use in service. It is assumed that you mean that sodium hydroxide rather than sodium ions would be released by reaction of chromates or dichromate with glycol. Nevertheless, the fact remains that other inhibitors were found to be more effective than sodium dichromate in our tests in this particular medium. It is possible that a more favorable result could be obtained by using the chromate, inasmuch as it gives a mildly alkaline solution. However, even after addition of dichromate to a Royal Oak tap water-ethylene glycol solution, the pH is still approximately 7.7, and although this starting solution is mildly alkaline, the dichromate is not effective as an inhibitor for XA-30 clad aluminum (this pertains only to the ethylene glycol-water solution).

The effect of light on the stability of the dichromate inhibitor in these tests is an unknown factor. Even in the presence of light, dichromate remained an effective inhibitor in tests run in water or isopropyl alcohol-water solutions.

#### End of Part 2 of 2 Parts

Any discussions of this article not published above  
will appear in the December, 1956 issue.

# The Cathodic Protection of Metallic Structures In Marine Environments\*

By W. A. BOWEN, JR.

## Introduction

ENVIRONMENT HAS a great deal to do with the rate at which corrosion attacks. Marine environments are notoriously conducive to the accelerated corrosion of metallic structures. The United States Navy in its extensive operation in and about the sea is constantly on the alert for effective corrosion mitigation measures. Cathodic protection is widely used and much effort is being expended investigating the technique and improving its effectiveness.

A cathodic protection system used in sea water has special characteristics. Sea water, in many respects offers an ideal medium for the application of cathodic protection. It has high conductivity. Large electric currents can be made to flow in sea water at reasonable power levels and the conductivity is fairly uniform and constant in time. For design purposes, a homogeneous medium can be assumed.

How should the anodes be placed? A general rule often followed is that an anode will supply, with reasonable uniformity, current to an extended area whose radius is of the same magnitude as the distance of the anode to the surface.

In practice, simple extended areas are not always encountered. Too often, the structure to be protected has an odd geometry with discontinuous surfaces, indentations, surfaces behind surfaces and projections. When this situation occurs, the final system design represents an engineering compromise based on a finite and often restricted number of anodes and the quality of protection desired. When the number of anodes is limited, there always result regions of over and under protection. The design must always be flexible enough to permit anode distribution changes in the field. Except for the crudest type of installation, it is almost universally required that current settings be made in the field, based on potential surveys both initially and at prescribed monitoring intervals.

A phenomenon occurs in low conductivity electrolytes which tends to improve the current distribution. When products are formed by the protection current changing the interface potential, the potential always changes in the direction to oppose the emf and current that produces it. The result is a reduction in the voltage gradient in the areas adjacent to the anode tending to spread the current over a larger area.

Equation (3) of Figure 1 indicates the relative importance of the polarization or back emf, and the



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## Abstract

Theoretical and practical considerations involved in using cathodic protection in sea water are covered, including anode location, polarization, economics and other factors. Specific cases of cathodic protection application are mentioned, including drydocks and ships. Means of checking the effectiveness of cathodic protection are reviewed. The importance of supervision by competent personnel is mentioned, as is automatic control of potentials. Other topics discussed include use of compartmented cells, effect of cathodic protection current on marine growth and problems involved in making cathodic protection automatic. 5.2.1

driving voltage on the spreading of the current on a cathodically protected surface. It is noted that ratio of  $\sigma$ , current density, to  $\sigma_0$  increases as  $V$  decreases and as  $\phi_0 - \phi$  increases. In sea water, the driving voltage,  $V$  remains small because of the high conductivity and  $\phi_0$  has the same magnitude in low or high conductivity media. If it is assumed in the steady state condition that the back emf  $\phi$ , is proportional to the current density  $\sigma$ , the ratio of current density at element  $T$  to the maximum current density  $\sigma_0$  is increased, for in equation (6),  $\frac{\sigma}{\sigma_0}$  is always larger than  $\frac{\partial}{\partial_0}$ , the normal distribution.

## Economic Considerations

In all corrosion mitigation, it is important that the cost of the measures does not exceed the cost resulting from the lack of protection. Preferably, the cost of protection should be only a small fraction of the money saved. Aside from the initial installation costs, provisional funds should be included for continued maintenance of cathodic protection systems. All too often a system is purchased, installed and forgotten. Providing for the continued maintenance of an installed cathodic protection system is very much a

\*Submitted for publication March 7, 1955. A paper presented at a meeting of the Western Region, National Association of Corrosion Engineers, Los Angeles, California, November 18, 1954.



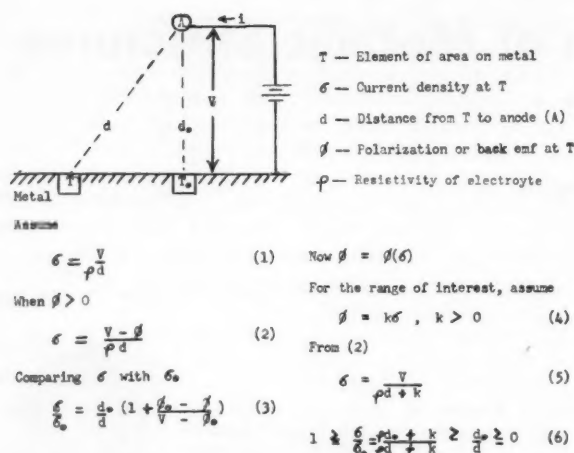


Figure 1—Throwing power of cathodic protection current.

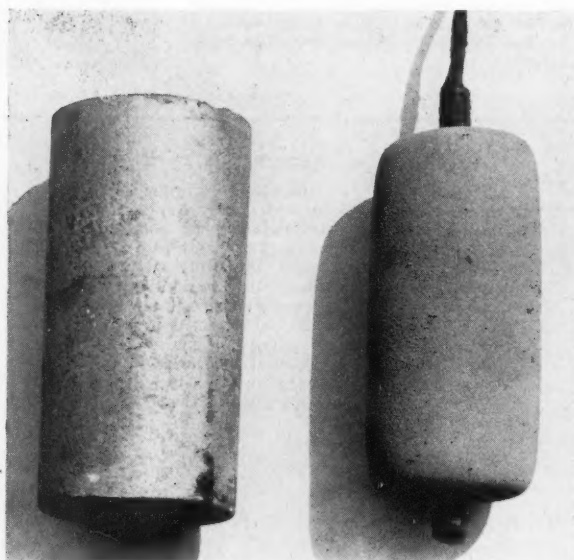


Figure 2—Magnesium anode as received new (left) and after four months use.

major problem today. A possible answer to the monitoring problem is discussed later.

It is almost self-evident that the most economical cathodic protection system uses a minimum number of anodes, the smallest amount of copper in cables, and the least current or electrical power to achieve protection. Good design requires sound tolerances to allow for system deterioration and contingencies.

Some materials and methods used in the application of cathodic protection in marine environments may be illustrated by two actual, yet typical, marine problems associated with underwater hull protection on floating drydocks.

The first and simpler problem was to design and install cathodic protection systems for isolated 1000-ton drydocks, utilizing the simplest anode configuration and the minimum current for adequate protection. Systems using active anodes and systems using passive anodes were tried. It was found that two 51-pound magnesium anodes suspended over the side

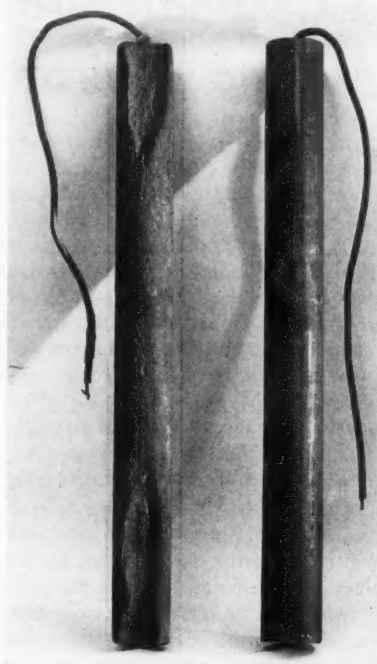


Figure 3—Three year old (left) and new graphite anode.

15 feet below keel level, one forward and one aft were more than adequate. Current limiting devices, rheostats, placed in each lead served to reduce the cathodic protection current and extend the anode life. About two anodes a year were expended in this installation.

Figure 2 shows the contrast between an unused magnesium anode and a similar anode after four months service. The impressed current system which used a rectifier and the worn anode shown beside a new one in Figure 3 gave adequate protection for three years. The single graphite anode was placed on the bottom 30 feet below keel under the center of the ship and supplied currents ranging from 6 to 14 amperes. Adequate protection was maintained for the three years with less than 30 percent deterioration of the graphite anode. Current 50 percent in excess of the anode manufacturer rating were used at times. It should be remembered that this is an experimental installation and does not represent conservative design.

The second problem involved a seven section floating drydock wherein all sections were to be incorporated into a cathodic protection system, utilizing a minimum of anodes, copper, and protection current. Originally, two of the basic plans shown in Figure 4 were considered. In one, Figure 4A, progressive IR voltage drops in the anode buss were to be balanced by equivalent drops in the negative return buss. In the second an anode buss was to be used as in Figure 4B.

The availability of an abundance of only one type of wire, No. 4AWC-neoprene-jacketed, caused the actual installation to be modified to that shown in Figure 4C. It was thought that uniform current dis-

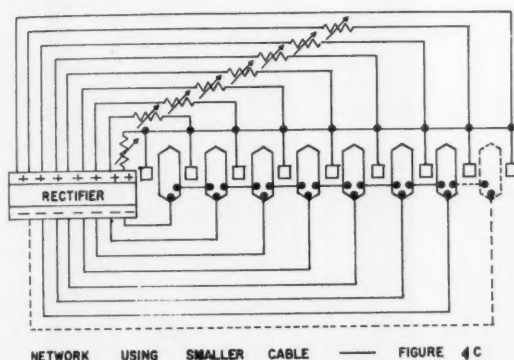
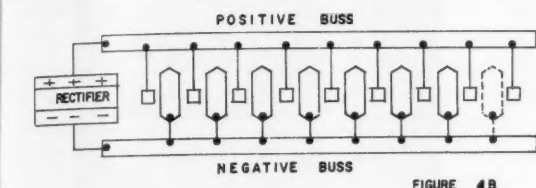
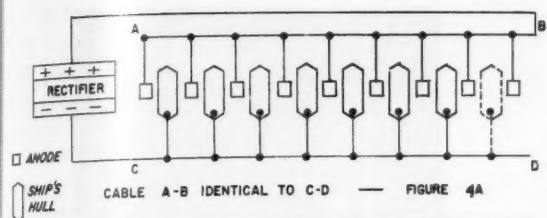


Figure 4—Three cable arrangements for sectional drydock.

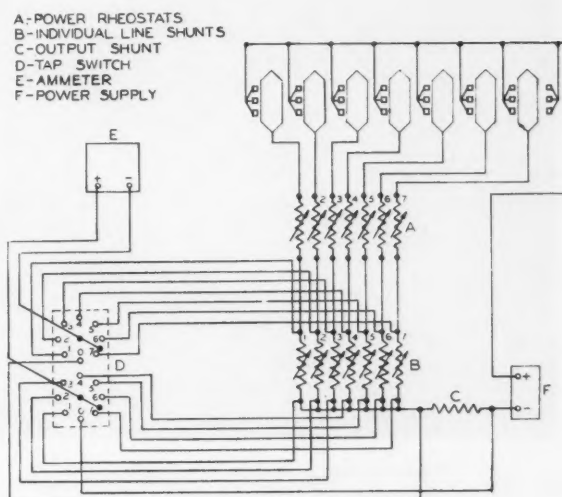


Figure 5—Control system for AFDB (Auxiliary Floating Drydock).

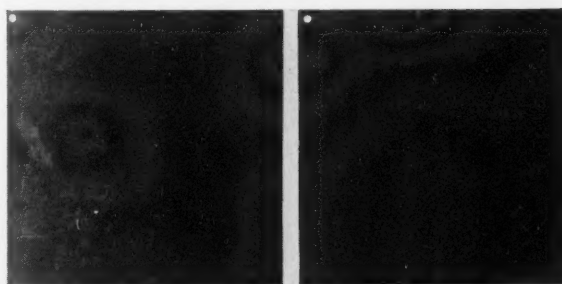


Figure 6—Protected (left) and unprotected coupons of mild steel after one year in sea water.

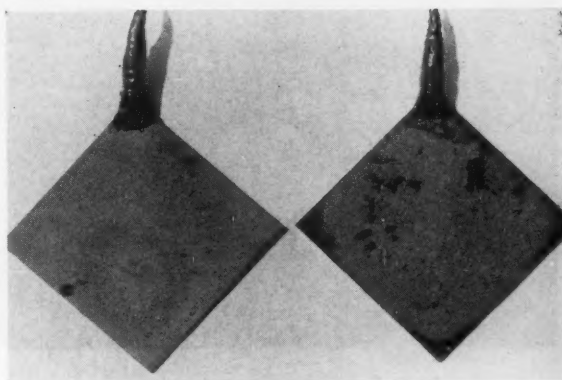


Figure 7—Protected (left) and unprotected coupons after one week of exposure in sea water.

tribution could be achieved with a symmetrical anode placement and provision to supply equal currents to each anode. The whole of the seven sections were to be bonded to effectively form an equipotential surface. This system worked satisfactorily using power from a rectifier at about half its rated 300-ampere capacity. At least, it worked satisfactorily for more than a year until overhaul on the sections began, one at a time. With some sections repainted and others waiting, the differences in bottom conditions were too great to obtain a uniform potential over all sections.

The present and preferred system for achieving a satisfactory current distribution is shown in Figure 5, wherein a new approach is used. The anodes were made equipotential and the current gathered by each hull was controlled by a rheostat inserted in each negative return lead. Once the proper current ratio was established with the rheostats, the over-all or total current was adjusted with a variable-transformer-controlled rectifier.

#### Determining Effectiveness of Cathodic Protection

How does one know that protection has been achieved? One can accept simple theory and assume protection when the potential to copper sulfate is maintained at 850 millivolts. Needless to say, this does not convince everyone and more positive proof is required. Three methods of demonstrating the effectiveness of cathodic protection are presented, methods which may be used when the structure it-

self cannot be weighed before and after the period of protection.

#### Coupon System

The first, or coupon system, consists of weighing plates or samples of the structure material and placing them in the same electrolyte as the structures and bonding them electrically to the cathodically protected structure. After a period of time the weight

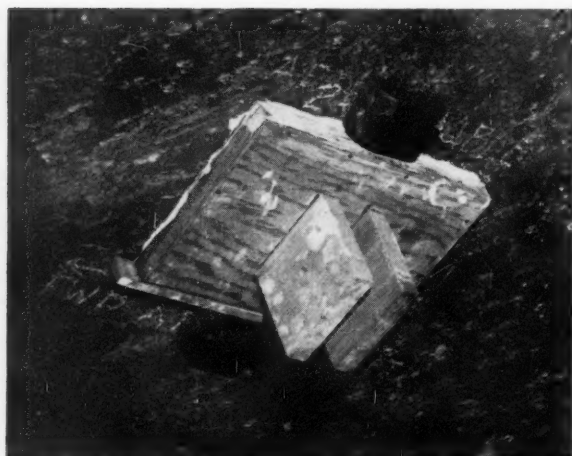


Figure 8—Hydrostone mold of hull surface.

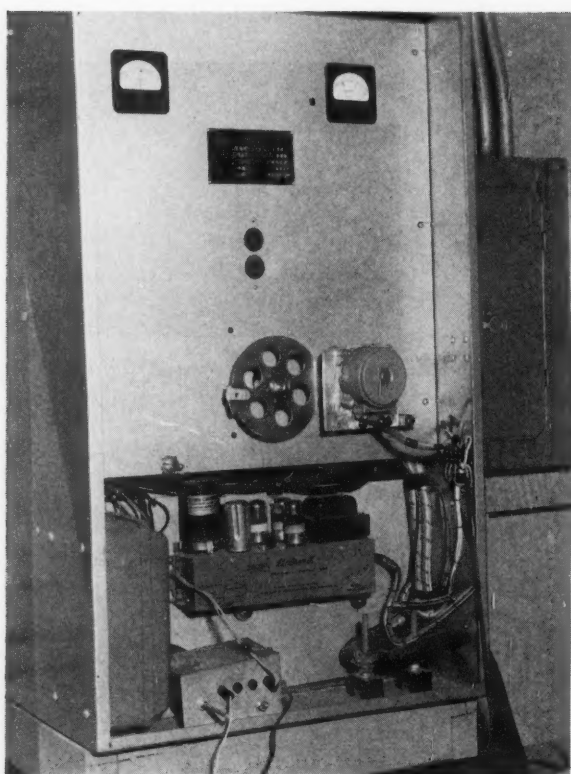


Figure 9—Automatic current controller.

loss of this sample is compared with an identical or similar sample left electrically unconnected. Figure 6 shows a comparison between two mild steel coupons each immersed in sea water for one year, one protected and the other not protected. The protected coupon lost about 17 grams/sq ft of exposed area; the unprotected coupon lost over 125 grams/sq ft and, in addition, the surface was marked with extensive pitting and channeling. Figure 7 shows a protected and unprotected coupon of mild steel after only one week of exposure in sea water.

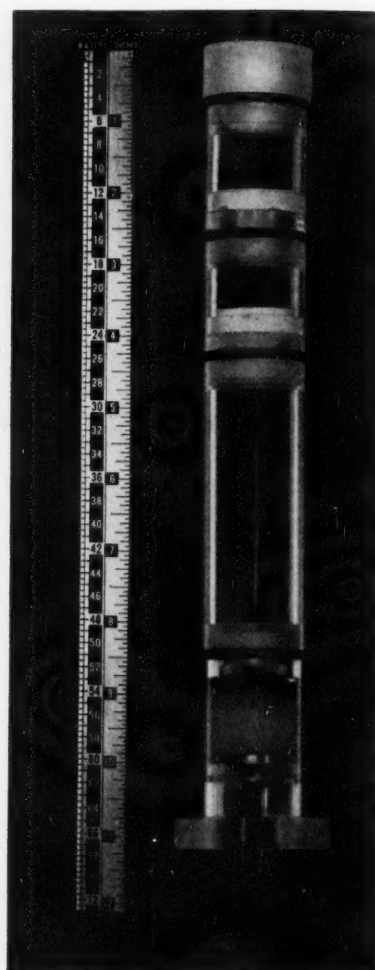


Figure 10—Compartmented cell.

### Photographic Methods

A second method of demonstrating cathodic protection effectiveness is to photograph marked sample areas on the structure before and after protection. At best photographic results are qualitative. Stereo and colored photography can improve this method.

### Hydrostone Molds

A third method, highly recommended for use in conjunction with photography, makes use of hydrostone molds. In this method a mold or imprint is made in relief of the sample area before and after protection. Hydrostone, a gypsum cement, has the required surface stability to hold the dimensions during the period of protection. Moreover, it is sufficiently fine textured to record fine detail in the surface. In the use of hydrostone, care must be exercised to avoid entrapment of air bubbles in the surface. Figure 8 shows a hydrostone mold being taken off a hull section while in drydock. Permanent magnets are used to hold the mold form to the surface.

The expensive problem, often overlooked, of the need for continued adjustment and maintenance of an installed system was mentioned earlier. Engineer-



ing time to measure potentials and adjust protection currents runs into large amounts of time with associated expense. To reduce this expense, incompetent personnel often are substituted who in turn compromise the degree of protection obtained.

### Automatic Control System

As with many other present day enterprises it is thought that a satisfactory answer to the problem of continued maintenance may lie in the field of automatic control. In this connection maintenance of the control system should not be confused with maintenance of the cathodic protection system. Vacuum-tube servo-systems have been developed to work in nearly every field of engineering and no doubt can be used to advantage in corrosion control. Figure 9 shows a continuous balance system in use on a floating drydock cathodic protection system which has worked satisfactorily for several months. By reputation, however, vacuum tube amplifiers are not considered as reliable as magnetic amplifiers which may be expected to give trouble-free operation in terms of years instead of months. Several references have appeared recently in which magnetic amplifiers are described in cathodic protection current control applications.

If an automatic control system is constructed in which the surface potential, referred to some reference half-cell, is compared with a pre-set steady potential, it will be found that it is a more difficult task to keep the reference half-cell potential constant than to handle the servo-components. Because a reference cell must have an ionic permeable membrane or barrier for conduction, contaminants do penetrate the cell and in a short time render it useless. Other approaches may be used in which passive conducting materials, graphite, lead, or platinum are used, not as a standard reference but to offer a steady potential. Contamination and polarization usually make them undependable in sea water.

Another approach is to use an anodic material such as zinc or magnesium. The self-cleaning action as corrosion progresses makes this type of monitoring electrode compare favorably with reference cells. One more attempt that has been made with limited success is the use of compartmented cells. An example is shown in Figure 10. The inevitable contamination is postponed because one or more compartments of pure reference electrolyte must be contaminated in turn before the pure metal electrode is reached. Elongated capillary tubes have been used to reduce the contamination rate, but an increase in the cell impedance resulted.

Here two problems must be solved, in order to make cathodic protection automatic and thereby to reduce the monitoring costs. One involves the development of a general-purpose magnetic amplifier having high input impedance. The output current should be controlled directly with saturable reactors, in contrast to motors turning contacts on variable transformers or rheostats.

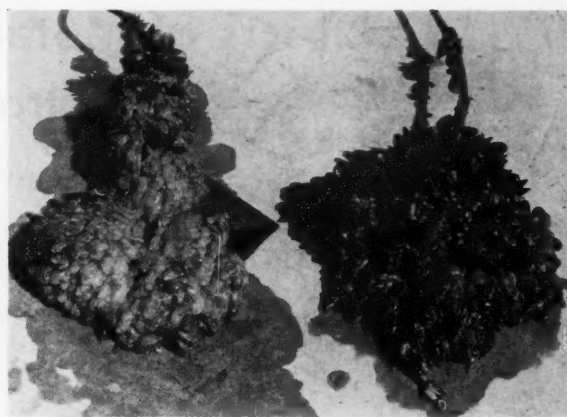


Figure 11—Marine growth in unprotected (left) and protected coupons.

The second, and in the writer's opinion by far the harder task, is the development of a reference half-cell whose constancy can be relied on for an indefinite period under a wide variety of environments and hard usage.

### Marine Growth

Marine growth consisting of barnacles, mussels, seasquirts, moss, etc., attach themselves firmly to underwater structures. Active ships in particular are seriously hampered in movement by the growth. Inquiry is often made as to the effect of cathodic protection currents on marine growth. Apparently, protection currents have little direct effect on the marine life although an interesting phenomenon occurs (see Figure 11). Two coupons are shown, one protected, the other unprotected. The protected coupon has the heavier growth and is completely covered. The unprotected coupon, part of which is bare, has a lighter growth of younger forms of life. The simple explanation tendered here is that the protected coupon offers a stable surface for attachment and growth. The surface of the unprotected coupon continually corrodes and sloughs off, leaving a fresh surface for new growth.

Superimposition of high-energy, short-duration pulses on the steady cathodic protection current has been proposed as a means of stimulating and affecting marine growth. Work of this nature is being planned at Harbor Beach, North Carolina, under Navy sponsorship. The results are being awaited with interest.

When cathodic protection is to be applied to a structure in the neighborhood of other structures which are to remain unprotected, the design problem becomes complex and, as such, is beyond the scope of this discussion. Cathodic protection of an isolated metallic structure in a marine environment can be simply and economically achieved using the materials and methods described.

Note: The opinions expressed in this article are those of the author and not necessarily those of the Navy Department.

# Effects of Metal Cations on the Corrosion of Iron in Acids\*

By HARRY C. GATOS

## Introduction

THE ROLE of insoluble corrosion products in the corrosion resistance of common metals and alloys has been the subject of extensive investigations. Soluble corrosion products, however, such as the ions of the common metals formed in acid solutions, have been studied only to a limited extent in connection with corrosion processes.

Among the various metal cations, the ferric ions have received the greatest attention.<sup>1,2,3,4,5</sup> Ferric ions accelerate considerably the corrosion of iron in acids. This acceleration constitutes a problem during acid-cleaning of ordinary steel equipment. In such operations,  $\text{Fe}^{+++}$  ions are formed from any ferric oxide scale present. They are corrosion accelerators to the extent that in their presence a number of corrosion inhibitors become ineffective. The effect of  $\text{Fe}^{+++}$  ions has been attributed to the cathodic reduction of  $\text{Fe}^{+++}$  to  $\text{Fe}^{++}$ .<sup>5</sup>

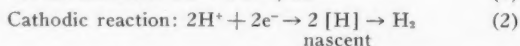
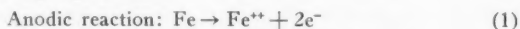
Because metal cations are commonly present during metallic corrosion by acids and because their role in corrosion processes has not as yet been studied systematically, it was felt worthwhile to investigate the effects of typical cations on the corrosion of iron in sulfuric acid, hydrochloric acid and acetic acid solutions. The following cations were chosen:<sup>(1)</sup>

1. Oxidizing:  $\text{Fe}^{+++}$ ,  $\text{Ce}^{++++}$ ,  $\text{Cu}^{++}$ ,  $\text{Cr}_2\text{O}_7^{--}$
2. Reducing:  $\text{Sn}^{++}$ ,  $\text{As}^{+++}$
3. Stable:  $\text{Fe}^{++}$ ,  $\text{Cr}^{+++}$ ,  $\text{Mn}^{++}$ ,  $\text{Ni}^{++}$

The present work also attempts to clarify the mechanisms involved during the action of these cations.

## Electrode Reactions in Acid Media

The corrosion of iron in nonoxidizing acids, like  $\text{H}_2\text{SO}_4$ ,  $\text{HCl}$ , and  $\text{HOAc}$ , can be described by the following equations:<sup>(2)</sup>



It is apparent that oxidizing substances, in general, and oxidizing cations, in particular, can participate in the cathodic reaction either directly or indirectly. For example, cations  $\text{M}^{+++}$ , when thermodynamically more stable in the oxidation state  $\text{M}^{++}$ , can be re-

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## Abstract

The corrosion of iron was studied in 1N sulfuric acid, 1N hydrochloric acid, and 1N acetic acid containing oxidizing, reducing, or stable metal cations. Oxidizing cations ( $\text{Fe}^{+++}$ ,  $\text{Ce}^{++++}$ ,  $\text{Cu}^{++}$ , and  $\text{Cr}_2\text{O}_7^{--}$ ) increased the corrosion rate of iron in these acids. The increased rate was found to be a linear function of the cation concentration for the concentration range studied (up to 0.1 g ions/liter). For the same oxidation-equivalent concentration the corrosion rate was proportional to the valence change which the metal cations underwent during the corrosion process. Reducing cations ( $\text{As}^{+++}$  and  $\text{Sn}^{++}$ ) decreased considerably the corrosion of iron in acids, whereas stable cations ( $\text{Fe}^{++}$ ,  $\text{Mn}^{++}$ ,  $\text{Cr}^{+++}$ , and  $\text{Ni}^{++}$ ) with the exception of  $\text{Ni}^{++}$  showed no effect.

The electrochemical action of the various cations was explained on the basis of corrosion data and electrode potential measurements. 3.8.2

duced directly at the local cathodes<sup>(3)</sup> together or in competition with  $\text{H}^+$  ions according to the equation:



It is also possible that  $\text{M}^{+++}$  can be reduced indirectly by the nascent hydrogen formed in reaction (2), as follows:



Reaction (3) should lead to increased current flowing through the local cells and, therefore, to increased corrosion. Reaction (4) should lead to the acceleration of reaction (2) and, therefore, to increased corrosion. In the case of  $\text{Fe}^{+++}$  ions, it has been shown that they accelerate the corrosion of iron in  $\text{H}_2\text{SO}_4$  solution by being cathodically reduced (reaction 3).<sup>1</sup>

Reducing cations ( $\text{M}_1^{++}$ , for example) can participate in the anodic reaction as follows:



Obviously, if reaction (5) displaces reaction (1),

\* Submitted for publication September 14, 1955. A paper presented at the Twelfth Annual Conference, National Association of Corrosion Engineers, New York, N. Y., March 12-16, 1956.

(1)  $\text{Cr}_2\text{O}_7^{--}$  ions, although not cations, are included in this study because they are encountered quite frequently in corrosion studies.

(2) All ionic symbols in this paper omit specific reference to solvation.

(3) The concept of local cells is not essential in explaining the electrochemical nature of metallic corrosion in acids. Both the anodic and the cathodic reaction can take place over the entire surface of a corroding metal.<sup>6</sup> Thus, corrosion by local cell action can be considered as a special case of electrochemical action. For the sake of clarity, however, the concept of local cells is employed throughout this paper.





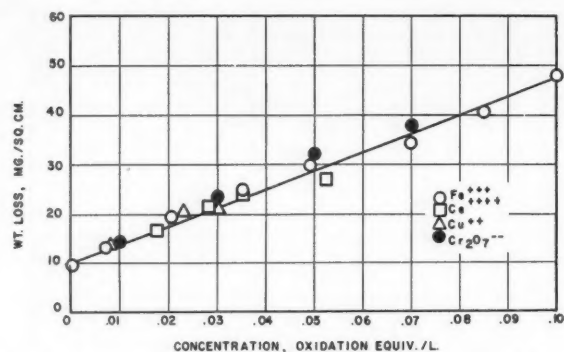


Figure 3—Corrosion of iron in 1 normal sulfuric acid containing oxidizing metal cations. Corrosion time was 46 hours.

bridges were renewed with every run. A pH-meter with an impedance of  $10^{10}$  to  $10^{12}$  ohms was connected in series with the potentiometer and served as nil current indicator. This arrangement yielded very reproducible results.

All electrode potential data reported in this paper have been converted to the standard hydrogen electrode scale. The sign convention adopted by the Electrochemical Society has been employed.

#### Effect of Metal Cations on the Corrosion of Iron in 1N H<sub>2</sub>SO<sub>4</sub>

**1. Oxidizing Cations.** From the potential diagrams it is apparent that Fe<sup>+++</sup>, Ce<sup>++++</sup>, Cu<sup>++</sup>, and Cr<sub>2</sub>O<sub>7</sub><sup>--</sup> ions in acid solutions tend to be reduced to the thermodynamically more stable states Fe<sup>++</sup>, Ce<sup>+++</sup>, Cu, and Cr<sup>+++</sup>, respectively.

The accelerating effect of the above oxidizing cations on the corrosion of iron in 1N H<sub>2</sub>SO<sub>4</sub> is shown in Figure 2, where the weight loss of the iron samples for 46-hour<sup>(4)</sup> periods is plotted against the concentration of the metal ions. In all cases, this effect is a linear function of the ion concentration for the concentration range indicated. For the same concentration, in g ions/liter, the accelerating effect increases with increasing valence change of the ions. Thus Fe<sup>+++</sup> and Ce<sup>++++</sup> ions, undergoing a valence change of one, accelerate the corrosion of iron to the same extent. Cu<sup>++</sup> ions, undergoing a valence change of two, exhibit twice the effect of Fe<sup>+++</sup> ions. Finally, Cr<sub>2</sub>O<sub>7</sub><sup>--</sup> ions, undergoing a valence change of three, exhibit three times the effect of Fe<sup>+++</sup> ions. The actual slopes of the Cu<sup>++</sup> and Cr<sub>2</sub>O<sub>7</sub><sup>--</sup> straight lines are greater than that of the Fe<sup>+++</sup> line by a factor of 2.1 and 3.2, respectively.

In the case of Cu<sup>++</sup>, it is of interest to note that corrosion caused by galvanic action resulting from deposition of metallic Cu on steel was found to be relatively small. This was found by immersing steel

<sup>(4)</sup> Within the 46-hour period, the corrosion rate of iron remains constant with time in the absence of oxidizing cations. In the presence of oxidizing cations, the corrosion of iron in acids is a first order reaction. Thus, it decreases slowly with time due to consumption of the cations.<sup>5</sup> The relative corrosion rates, however, are not time-dependent for the cation concentration range considered. Thus, 46-hour rather than shorter periods were employed, in order to minimize errors resulting from small weight losses.

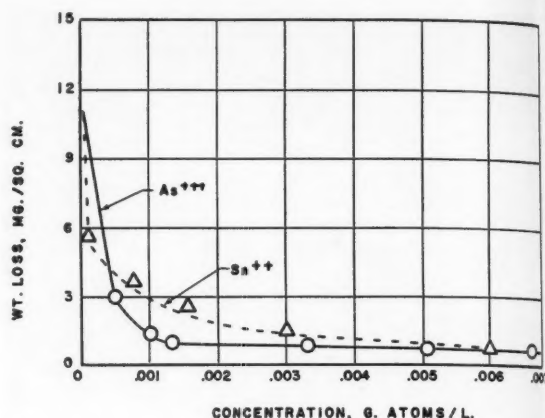


Figure 4—Corrosion of iron in 1 normal sulfuric acid containing reducing metal cations. Corrosion time was 46 hours.

samples in CuSO<sub>4</sub> solution for a few minutes to secure a copper deposit, washing them in 1N H<sub>2</sub>SO<sub>4</sub>, and then allowing them to corrode in Cu<sup>++</sup>-free 1N H<sub>2</sub>SO<sub>4</sub>. Their corrosion rates were only 25 percent higher than those obtained in 1N H<sub>2</sub>SO<sub>4</sub> in the absence of Cu. Similar results were obtained by coupling the steel samples with solid Cu. The data for Cu<sup>++</sup> shown in Figure 2 have been corrected for galvanic action of the deposited Cu.

In Figure 3, the increase in corrosion caused by Cu<sup>++</sup> and Cr<sub>2</sub>O<sub>7</sub><sup>--</sup> has been adjusted to a valence change of one (i.e., divided by two and three, respectively) and the results plotted as in Figure 2. It can be seen from Figure 3 that all oxidizing ions studied accelerate the corrosion of iron in 1N H<sub>2</sub>SO<sub>4</sub> to the same extent, when present in oxidation-equivalent amounts. This quantitative relationship between the valence change of the oxidizing cations and the increase in corrosion indicates that the oxidizing cations are reduced directly at the local cathodes (reaction 3) rather than by nascent hydrogen (reaction 4). Reaction (4), of course, also could lead to an increase in corrosion by causing an acceleration of reaction (2), but not necessarily to the above relationship.

The linear relationship, pointed out above, between the corrosion rate and the concentration of the oxidizing cations suggests that the corrosion rate,  $dm/dt$ , is controlled by the rate of diffusion of these cations to the metal surface. This seems to be true because the rate of diffusion is proportional to the concentration gradient of the cations from the bulk of the solution to the metal-liquid interface.

Thus,

$$\frac{dm}{dt} = K(C - C_s)$$

where:

- K = reaction constant
- C = concentration of the reactant in the bulk of the solution, and
- C<sub>s</sub> = concentration of the reactants in the solution at the metal-liquid interface

The concentration gradient  $C - C_s$  is actually equal to the concentration in the bulk of the solution,

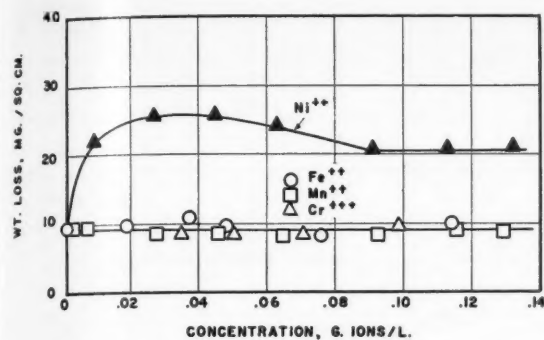


Figure 5—Corrosion of iron in 1 normal sulfuric acid containing stable metal cations. Corrosion time was 46 hours.

because chemical reactions at metal-liquid interfaces are extremely rapid. Thus the concentration of the reactants at these interfaces is zero, at any given time.<sup>8</sup>

In the case of iron corroding in 1N H<sub>2</sub>SO<sub>4</sub> containing Fe<sup>3+</sup> it was found that between the concentrations 0.15 and 0.47 Fe<sup>3+</sup> g ions/liter, the corrosion rate is a linear function of the Fe<sup>3+</sup> concentration.<sup>5</sup> The slope of this linear relationship, however, is considerably greater than that of Figure 3. Furthermore, it was found that H<sup>+</sup> ion reduction was suppressed almost completely in the range of 0.15 to 0.47 Fe<sup>3+</sup> g ions/liter and, therefore, did not contribute to the dissolution process.

This was not the case, however, for low concentrations of Fe<sup>3+</sup>. On this basis it was concluded that above 0.15 g ions/liter the diffusion of Fe<sup>3+</sup> ions to the metal surface is the rate determining step. Below 0.15 g ions/liter, although the system is phenomenologically under diffusion control, it is difficult to strictly define the rate determining step. In the present study no effort was made to study the H<sup>+</sup> ion reduction. It is believed, however, that here also the corrosion process is possibly but not necessarily under oxidizing cation diffusion control.

**2. Reducing Cations:** The results obtained with the reducing cations As<sup>3+</sup> and Sn<sup>2+</sup> are shown in Figure 4. It can be seen that both cations are quite effective corrosion inhibitors under the present experimental conditions. The inhibiting action of As<sup>3+</sup> on iron in H<sub>2</sub>SO<sub>4</sub> is well known.<sup>9,10</sup> It is significant to note, however, that both of the above cation species are effective to the same extent under the present experimental conditions.

In the presence of As<sup>3+</sup>, metallic As was observed on the iron sample. The high hydrogen overvoltage of metallic As has been considered by previous investigators<sup>10</sup> as the reason for the observed inhibition. During this investigation it was found that no inhibition takes place by depositing metallic As on iron samples from As<sup>3+</sup> solutions, and then immediately immersing these samples in As<sup>3+</sup>-free 1N H<sub>2</sub>SO<sub>4</sub>. It is, of course, possible that the As deposit was undermined upon immersion in the As<sup>3+</sup>-free H<sub>2</sub>SO<sub>4</sub> solution and, thus, was not in electrical contact with the iron substrate. No metallic Sn was detected on iron samples in the Sn<sup>2+</sup> solutions.

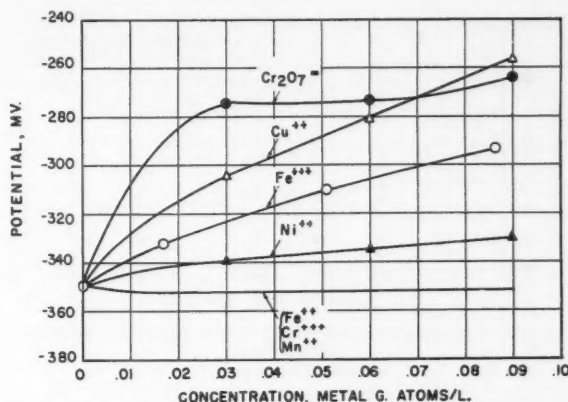


Figure 6—Potential of iron after two hours in 1 normal sulfuric acid containing metal cations.

The action of the above cations will be further discussed later.

**3. Stable Cations:** With the exception of Ni<sup>2+</sup>, stable cations showed no effect on the corrosion of iron (Figure 5). Similarly, the corrosion products of the iron samples did not affect the corrosion of iron (i.e., iron specimens corroded under their normal rate in 1N H<sub>2</sub>SO<sub>4</sub> in which other iron specimens were previously immersed for 46 hours).

Ni<sup>2+</sup> ions, although thermodynamically stable in acid solutions, as indicated by the corresponding potential diagram, are obviously reduced in the presence of iron, which is a stronger reducing agent than Ni:



In agreement with the above, small amounts of metallic nickel were detected on the iron corroding in 1N H<sub>2</sub>SO<sub>4</sub> containing Ni<sup>2+</sup>.

#### Potential of Iron in 1N H<sub>2</sub>SO<sub>4</sub> Containing Metal Cations

The corrosion data reported above were supplemented by potential measurements. The results are shown in Figures 6 and 7. The potentials appearing in Figure 6 represent the values obtained after the iron was immersed for two hours in the corresponding solution. As a general rule, in all solutions, the potential reached a steady state in less than two hours and remained constant for several hours thereafter. It eventually drifted toward the potential of iron in 1N H<sub>2</sub>SO<sub>4</sub>, containing no metal cations. Typical potential time curves are shown in Figure 8.

As shown in Figure 6, the stable cations Fe<sup>3+</sup>, Cr<sup>3+</sup>, and Mn<sup>2+</sup> do not affect the potential of iron under the present experimental conditions. Ni<sup>2+</sup> ions cause a shift of the potential of iron toward more cathodic values. In the presence of oxidizing cations, the shift of the potential toward more cathodic values becomes quite pronounced, and in the case of Fe<sup>3+</sup> and Cu<sup>2+</sup> increases with cation concentration for the concentration range indicated. In the presence of Cr<sub>2</sub>O<sub>7</sub><sup>2-</sup>, the potential shifts rapidly at low concentrations, and then changes only slightly.

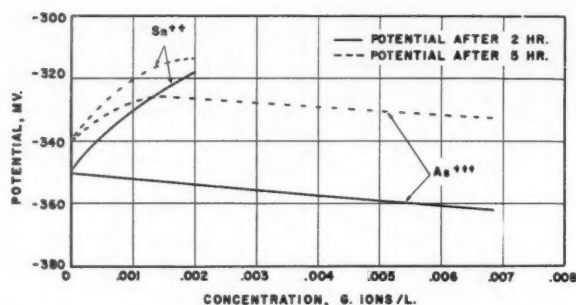


Figure 7—Potential of iron in 1 normal sulfuric acid containing reducing metal cations.

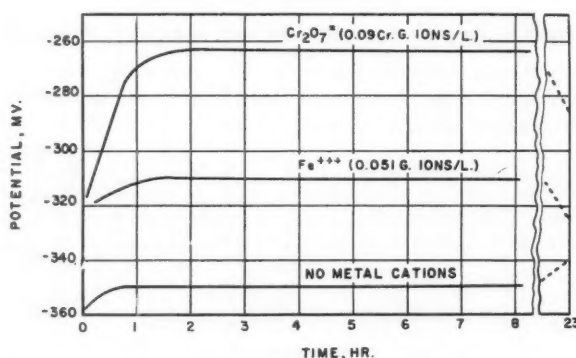


Figure 8—Typical potential-time curves of iron in 1 normal sulfuric acid in the absence and presence of metal ions.

The above shift of the electrode potential toward more cathodic values in the presence of oxidizing ions leads to a partial or complete suppression of the reduction of  $H^+$  ions. As a result the reduction of the oxidizing ions becomes the main cathodic reaction. By plotting the electrode potential against the logarithm of the current density corresponding to the various concentrations of oxidizing ions shown in Figure 2, a linear relationship is observed (Figure 9-I). The current density was calculated from weight loss and by assuming a roughness factor of 4.0.<sup>4</sup> The equation describing this relationship is:

$$\text{Potential} = -0.22 + 0.08 \log i$$

where  $i$  is the current density in  $\text{ma}/\text{sq. cm.}$  This relationship was first observed by Makrides, Komodromos and Hackerman<sup>4</sup> in the dissolution of iron in HCl solution containing various depolarizers. According to the above authors this plot could be considered, with some limitations, as an approximate polarization curve for the anodic reactions. Thus, the electrochemical process of the dissolution of iron in acids in the presence of oxidizing ions can be represented schematically as shown in Figure 9-II.<sup>4</sup> Curve AA' is the anodic polarization curve and CC' the polarization curve of the reduction of  $H^+$  ions in the absence of oxidizing ions. Curves  $C_1C_1'$  and  $C_2C_2'$  represent the polarization curves of the reduction of oxidizing ions in two different concentrations (concentration for  $C_1C_1'$  is greater than for  $C_2C_2'$ ). The system as shown is under diffusion control. In this diagram the contribution of the  $H^+$  reduction to the

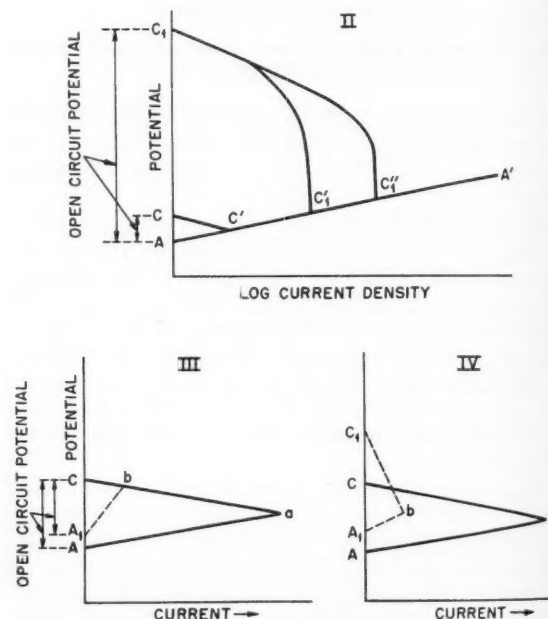
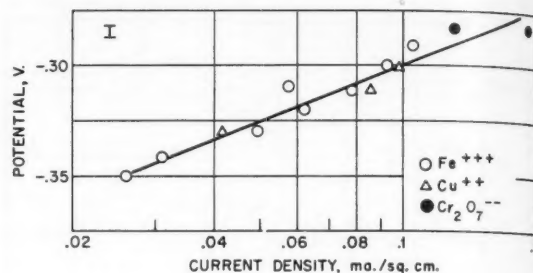
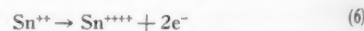


Figure 9—Electrode polarization diagrams. I—Potential of iron in 1 normal sulfuric acid containing oxidizing cations as a function of log current density calculated from weight loss. II, III and IV—Schematic polarization diagrams of iron in 1 normal sulfuric acid containing oxidizing cations,  $\text{Sn}^{++}$  and  $\text{As}^{+++}$ , respectively.

corrosion current is neglected in the presence of oxidizing ions.

In contrast to the cases discussed above, in the presence of  $\text{As}^{+++}$  and  $\text{Sn}^{++}$  the potential of iron reaches a steady-state value within five hours, rather than within two hours. In the presence of  $\text{Sn}^{++}$  (Figure 7), the potential of iron after two, as well as after five hours, is shifted toward more cathodic values. The shift increases with increasing  $\text{Sn}^{++}$  concentration. Inasmuch as no metallic tin was detected on the inhibited iron samples it is believed that the shift of potential is caused by the partial or complete suppression of the anodic reaction 1 by the following reaction:



A schematic diagram of the action of  $\text{Sn}^{++}$  is shown in Figure 9-III. Because of the low solubility of  $\text{Sn}^{++}$  in 1N  $\text{H}_2\text{SO}_4$ , the concentration range of  $\text{Sn}^{++}$  investigated was quite small.

In the presence of  $\text{As}^{+++}$ , the potential of iron after two hours shifts toward more anodic values, and



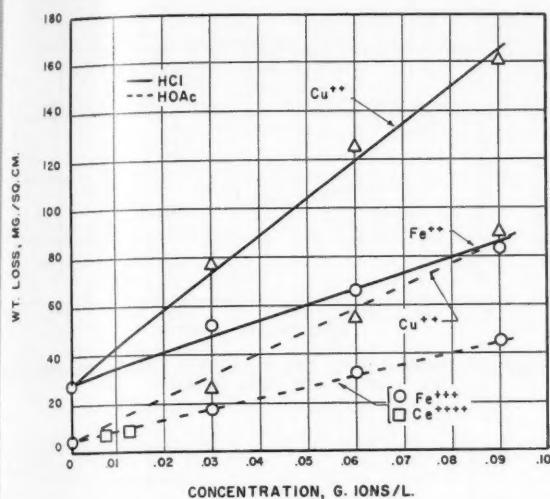


Figure 10—Corrosion of iron in 1 normal HCl and in 1 normal HOAc containing oxidizing metal cations. Corrosion time was 46 hours.

after five hours toward more cathodic values within the concentration range indicated. This behavior of the potential of iron is believed to result from the disproportionation of  $As^{+++}$  to metallic As and  $As^{++++}$  according to the reaction:



The deposition of As leads to a new polarization curve of  $H^+$  ion reduction and the oxidation of  $As^{+++}$  to  $As^{++++}$  to a new anodic polarization curve as shown schematically in Figure 9-IV. Thus, the over-all shift of the potential of the local cells after five hours toward more cathodic values is the result of new anodic and cathodic polarization, in view of the large decrease in corrosion, and therefore, the large decrease in the local cell current, which takes place in the presence of  $As^{+++}$ . The cathodic polarization is manifested first (Figure 7) because the corrosion process at hand is probably under cathodic control.

#### Effect of Metal Cations on the Corrosion of Iron in 1N HCl and 1N HOAc

In 1N HCl and in 1N HOAc, the action of the metal cations on the corrosion of iron is, with a few exceptions, similar to that observed in 1N  $H_2SO_4$ .

**1. Oxidizing Cations:** Figure 10 illustrates the results obtained with  $Fe^{+++}$  and  $Cu^{++}$ .  $Ce^{++++}$  ions are stable only at low concentrations in HOAc and not at all in HCl. As observed in the case of  $H_2SO_4$ , here also for the same molar concentration, the accelerating effect of  $Cu^{++}$  ions in both acids is approximately twice as large as that of  $Fe^{+++}$ .

The action of  $Cr_2O_7^{--}$  on the corrosion of iron in HCl and in HOAc is different from that in  $H_2SO_4$  if the action of  $Fe^{+++}$  and  $Cu^{++}$  is considered. Thus, in HCl the accelerating effect of  $Cr_2O_7^{--}$  is less than that caused by  $Cu^{++}$ . In HOAc,  $Cr_2O_7^{--}$  ions inhibit

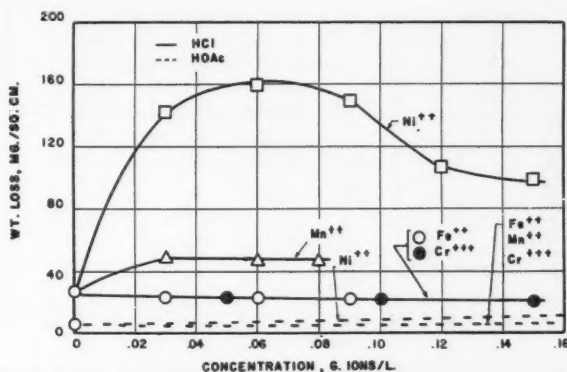


Figure 11—Corrosion of iron in 1 normal HCl and 1 normal HOAc containing stable metal cations. Corrosion time was 46 hours.

corrosion completely when their concentration exceeds 0.025M. Obviously, in these acids the well-known inhibiting properties of  $Cr_2O_7^{--}$  ions are exhibited at lower concentrations of  $Cr_2O_7^{--}$  than in  $H_2SO_4$ . The action of  $Cr_2O_7^{--}$  will be discussed in greater detail later.

In HOAc,  $Cu^{++}$  ions led to a most insidious form of corrosion. In contrast to the nonadherent and porous Cu deposits formed on steel from  $H_2SO_4$  and HCl containing  $Cu^{++}$ , the Cu deposits formed from HOAc were quite adherent and dense, but contained a small number of macroscopic cracks. Thus, the small area of the steel surface exposed by these cracks suffered the total amount of corrosion. Probably for this reason the results were not very reproducible.

As in the case of  $H_2SO_4$ , here also the simple galvanic effect of the deposited Cu accounted for only a small portion of the total corrosion. Thus, under the present experimental conditions, it is the process of reduction of  $Cu^{++}$  to metal, rather than the presence of the metallic Cu per se, that is important in the over-all corrosion of steel.

**2. Stable Cations:** The results obtained with stable cations in 1N HCl and 1N HOAc are shown in Figure 11. With the exception of  $Ni^{++}$ , stable cations do not affect the corrosion of iron. The accelerating effect of  $Ni^{++}$  is quite pronounced, particularly in HCl. In all three acids, this effect increases at first and then decreases with increasing  $Ni^{++}$  concentration. In that respect the accelerating effect of  $Ni^{++}$  is basically different than that of the oxidizing cations. It appears that  $Ni^{++}$  ions are reduced by metallic iron as was pointed out above. It is not likely that they are reduced by the evolved hydrogen, as Ni is above hydrogen in the electromotive force series.

**3. Reducing Cations:** As in the case of  $H_2SO_4$ , the reducing cations act as inhibitors in HCl (Figure 12). It will be noted that as an inhibitor,  $As^{+++}$  ions are more effective in HCl than  $Sn^{++}$ . In 1N HOAc, the solubility of these cations is quite limited. Thus, only a few experiments were performed with  $Sn^{++}$ . It was found that in the presence of less than 0.005  $Sn^{++}$  g ions/liter, the corrosion of iron was completely inhibited.

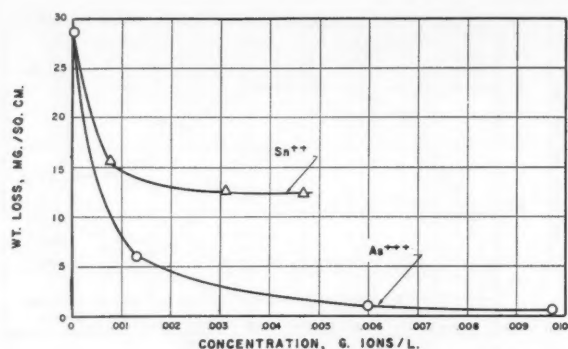


Figure 12—Corrosion of iron in 1 normal HCl containing reducing metal cations. Corrosion time was 46 hours.

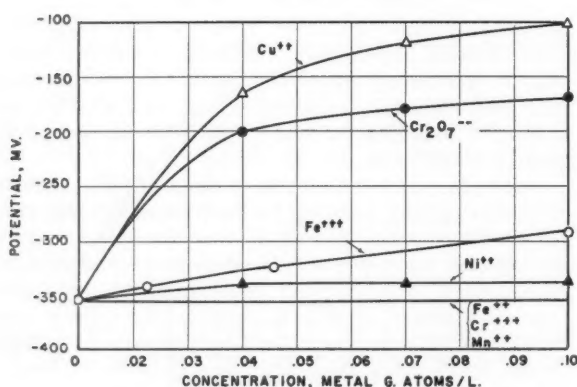


Figure 13—Potential of iron after two hours in 1 normal HCl containing metal cations.

#### Potential of Iron in 1N HCl and in 1N HOAc Containing Metal Cations

The electrode potential of iron in 1N HCl and in 1N HOAc containing various amounts of metal cations is shown in Figures 13, 14, and 15. In HCl, as in  $\text{H}_2\text{SO}_4$ , the stable cations have no effect on the potential of iron (Figure 13).  $\text{Ni}^{++}$  ions shift the potential to a small extent toward more cathodic values.

Oxidizing cations cause a pronounced shift of the potential. The shift caused by  $\text{Cr}_2\text{O}_7^{--}$ , however, is not as large as that caused by  $\text{Cu}^{++}$ . This is consistent with the fact that the acceleration of the corrosion caused by  $\text{Cr}_2\text{O}_7^{--}$  was not as large as that caused by  $\text{Cu}^{++}$ . It is believed that in this case the reduction of the  $\text{Cr}_2\text{O}_7^{--}$  at the local cathodes is hindered by the chemisorption of  $\text{Cr}_2\text{O}_7^{--}$ , probably at anodic areas. Such chemisorption can lead to an over-all polarization of the local cells, and thus to a decrease in the reduction rate of  $\text{Cr}_2\text{O}_7^{--}$ .

The effect of  $\text{As}^{+++}$  and  $\text{Sn}^{++}$  on the potential of iron in 1N HCl (Figure 14) is similar to the effect observed in 1N  $\text{H}_2\text{SO}_4$  (Figure 7), except that in HCl a steady-state potential is reached within two hours.

In 1N HOAc, as in 1N  $\text{H}_2\text{SO}_4$  and in 1N HCl, stable cations do not affect the potential of iron (Figure 15), with the exception of  $\text{Ni}^{++}$ . The oxidizing

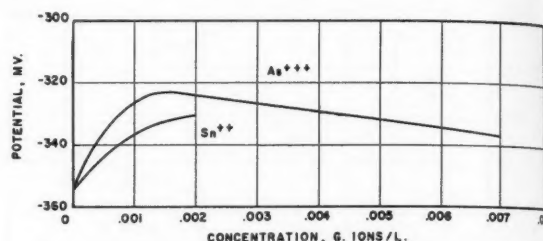


Figure 14—Potential of iron after two hours in 1 normal HCl containing reducing metal cations.

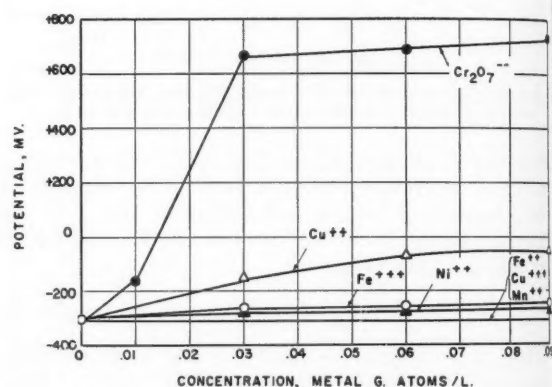


Figure 15—Potential of iron after two hours in 1 normal HOAc containing metal cations.

cations  $\text{Fe}^{+++}$  and  $\text{Cu}^{++}$  shift the potential of iron toward more cathodic values. The shift caused by  $\text{Cr}_2\text{O}_7^{--}$  is particularly pronounced. In view of the fact that  $\text{Cr}_2\text{O}_7^{--}$  at relatively low concentrations inhibits effectively the corrosion of iron in HOAc (Figure 16), this shift should be attributed to anodic polarization. The anodic action of  $\text{Cr}_2\text{O}_7^{--}$  when inhibiting corrosion has been discussed by previous investigators.<sup>11</sup>

The effect of  $\text{As}^{+++}$  and  $\text{Sn}^{++}$  on the potential of iron in HOAc was not studied, as the solubility of these ions in HOAc is very limited.

#### Effect of $\text{Cr}_2\text{O}_7^{--}$ on the Corrosion of Iron

It was pointed out above that in 1N  $\text{H}_2\text{SO}_4$ , the action of  $\text{Cr}_2\text{O}_7^{--}$  on the corrosion of iron is consistent with that of the other oxidizing ions within the concentration range indicated (Figures 2 and 3). In the case of HCl, however, the accelerating effect of  $\text{Cr}_2\text{O}_7^{--}$  is smaller than that of  $\text{Cu}^{++}$ . In HOAc, when present in relatively small concentrations,  $\text{Cr}_2\text{O}_7^{--}$  ions are effective corrosion inhibitors.

The effect of  $\text{Cr}_2\text{O}_7^{--}$  in concentrations up to 0.4 Cr g atoms/liter on the corrosion of iron in all three acids under study is shown in Figure 16. It can be seen that in  $\text{H}_2\text{SO}_4$  the accelerating effect of  $\text{Cr}_2\text{O}_7^{--}$  decreases above the concentration of approximately 0.15 Cr g atoms/liter. At this concentration, the elec-

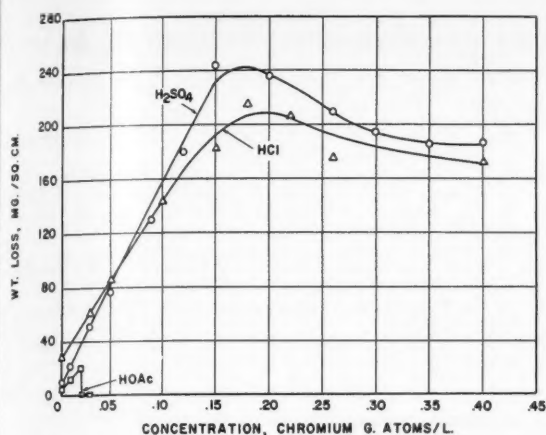


Figure 16—Corrosion of iron in 1 normal sulfuric acid, in 1 normal hydrochloric acid and in 1 normal acetic acid containing  $\text{Cr}_2\text{O}_7^{--}$ .

trode potential of iron is more cathodic by about 100 mv than in 0.09 Cr g atoms/liter. Apparently, pronounced anodic polarization begins to take place at this concentration.

In 1N HCl and in 1N HOAc,  $\text{Cr}_2\text{O}_7^{--}$  ions polarize the local anodes of iron at smaller concentrations than 1N  $\text{H}_2\text{SO}_4$ . As is shown in Figure 16, the corrosion of iron in HOAc is completely inhibited in the presence of about 0.025 Cr g atoms/liter. In HCl the action of  $\text{Cr}_2\text{O}_7^{--}$  is similar to that in  $\text{H}_2\text{SO}_4$ , except that in the former the corrosion of iron increases more slowly with  $\text{Cr}_2\text{O}_7^{--}$  concentration than in the latter. This is believed to be due to the fact that in HCl polarization of the local anodes of iron takes place at smaller  $\text{Cr}_2\text{O}_7^{--}$  concentrations than in  $\text{H}_2\text{SO}_4$ . Potential measurement in HCl is consistent with these views.

As shown in Figure 17, even at 0.03 Cr g atoms/liter in 1N HCl, the potential of iron is considerably more cathodic than in the absence of  $\text{Cr}_2\text{O}_7^{--}$ . With time, however, the potential of iron shifts toward more anodic values. This shift appears to be caused by the consumption of  $\text{Cr}_2\text{O}_7^{--}$  with time. The higher the initial  $\text{Cr}_2\text{O}_7^{--}$  concentration, the longer it takes for the shift of the potential toward more anodic values. Prior to this shift of potential, the corrosion of iron was found to be considerably less than after the shift. For purposes of comparison, however, the corrosion of iron in the presence of  $\text{Cr}_2\text{O}_7^{--}$  is expressed in all cases in weight loss per 46 hours (Figure 16).

### Summary

In a previous investigation of the acceleration of the dissolution of iron by  $\text{Fe}^{++}$  in  $\text{H}_2\text{SO}_4$ , the author<sup>5</sup> found that at  $\text{Fe}^{++}$  concentrations between approximately 0.15 and 0.47 g ions/liter the rate-determining step of the corrosion process is the diffusion of  $\text{Fe}^{++}$  to the metal surface where they are reduced instantaneously. At lower  $\text{Fe}^{++}$  concentrations the  $\text{H}^+$  ion reduction contributes to some extent to the corrosion process. The corrosion

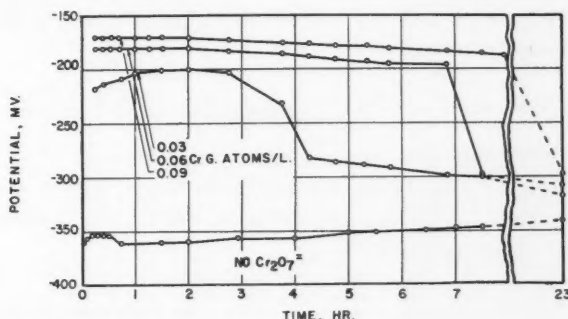


Figure 17—Potential-time curves of iron in 1 normal hydrochloric acid containing  $\text{Cr}_2\text{O}_7^{--}$ .

rate, however, is still a linear function of  $\text{Fe}^{++}$  concentration.

The results reported in the present investigation show that the corrosion rate of iron in several non-oxidizing acids (1N  $\text{H}_2\text{SO}_4$ , 1N HCl, and 1N HOAc), containing a number of oxidizing cations ( $\text{Fe}^{+++}$ ,  $\text{Ce}^{++++}$ ,  $\text{Cu}^{++}$ , or  $\text{Cr}_2\text{O}_7^{--}$ ) in concentrations less than 0.1 g ions/liter, also increases linearly with cation concentration (Figures 2, 10 and 16). The action of  $\text{Cr}_2\text{O}_7^{--}$  at the local cathodes is attenuated in concentrations above 0.1 Cr g atoms/liter in the case of  $\text{H}_2\text{SO}_4$ , and HCl, and above 0.025 Cr g atoms/liter in the case of HOAc (Figure 10). This behavior is probably caused by the polarization of the local anodes at the above  $\text{Cr}_2\text{O}_7^{--}$  concentrations.

During the corrosion process, it is believed that the oxidizing cations are directly reduced at the local cathodes to their more stable oxidation states causing an equivalent dissolution of iron at the local anodes, in accordance with Faraday's law. Reduction of the oxidizing cations by nascent hydrogen is not likely under the present experimental conditions, as the corrosion-rate-cation concentration relationship cannot be explained on this basis.

In view of the fact that oxidizing cations accelerate the corrosion of iron to the same extent for a given oxidation equivalent concentration (Figure 3), it appears that the rates of diffusion of these cations to the metal surface are approximately the same under the present experimental conditions.

The reducing cations studied ( $\text{As}^{+++}$  and  $\text{Sn}^{++}$ ) inhibit effectively the corrosion of iron in acids. During inhibition, they shift the electrode potential of iron toward more cathodic values, which is indicative of anodic polarization. It is believed that this shift is brought about by the oxidation of  $\text{Sn}^{++}$  to  $\text{Sn}^{+++}$ , and the disproportionation of  $\text{As}^{+++}$  to As and  $\text{As}^{++++}$ .

Cations which are stable in acid solutions ( $\text{Fe}^{++}$ ,  $\text{Cr}^{+++}$ , and  $\text{Mn}^{++}$ ) exhibit no effect on the corrosion of iron in the acids studied because they cannot participate in either the anodic or the cathodic reactions.  $\text{Ni}^{++}$  ions, although stable in acid solutions,



are reduced in the presence of iron and, thus, increase its corrosion. In contrast to the increase in corrosion caused by the oxidizing cations, however, the increase caused by  $\text{Ni}^{++}$  presents a maximum (Figures 5 and 11) within the cation concentration range studied.

### Acknowledgment

The author expresses his appreciation to C. T. Cinaglia and A. M. Madarassy for their skillful assistance and many suggestions during the course of this investigation.

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will appear in the December, 1956 issue.**

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# Cathodic Protection of Lead Cables in an Urban Area<sup>\*</sup>

By L. M. PLYM

## Introduction

CATHODIC PROTECTION systems differ from one another because of the varying field conditions encountered. Primary consideration must be given to the size and distribution of the plant to be protected. The type and location of the ground bed or anode as well as the soil resistances also must be considered.

While experience and calculations make possible an estimate of the current and voltage requirements, it is generally desirable that they be determined by measurement. This paper describes the work done in establishing a representative system. It also covers several varieties of cathodic protection arrangements.

In Chicago, the Illinois Bell Telephone Company employs six teams of two men each to survey the 4,000 miles of underground cable plant and to maintain the corrosion protection systems. Because stray currents are found in all this area, half cells are not used. At present the company relies on clean lead plate earth contacts. The cable plant is regarded as safe if it measures  $-0.1$  volts or more to manhole bottom or spare duct.

In several locations, cable failures have been experienced where these tests have shown good conditions. Two causes of failure have been found. Cathodic corrosion may occur in the presence of salt which is used to prevent the formation of ice on the streets.

## Duct Surveys

In other cases positive potentials have been found in the ducts between manholes, and the failures evidently were caused by these anodic conditions. Tests to discover these conditions are called "duct surveys." A one foot section of cable sheath is pulled through a spare duct and measurements made every three to ten feet, depending upon conditions. The duct sections are three feet long and resistance to ground is low at many of the joints. The voltage between the main cables and this one-foot slug is measured with a high sensitivity voltmeter (50,000 ohms per volt). A low resistance milliammeter is then substituted for the voltmeter. If current flows from cables to slug and it exceeds two milliamperes, it is felt that the cable life may be appreciably shortened by reason of corrosive anodic attack. Incidentally, the author is concerned because this current exceeds 10 milliamperes at one location.

For the third test, the resistance is measured with a Vibroground which is a bridge type tester employing a reversing vibrator circuit to avoid polarization effects. Often this resistance measures more than 1,000 ohms but in one location the measurement



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## Abstract

An account is given of steps taken in establishing a cathodic protection system for lead covered telephone cables in an urban area. Practical applications for the following system arrangements are given: distributed ground beds, forced current through a drainage system, distributed negative connections to several underground cables, and duct anodes. The paper includes the steps taken to prevent damage to surrounding underground plants in the installation and use of these systems.

5.2.1

was only 4 ohms. This occurred in a river tunnel where the duct water was highly alkaline. Attempts to change this condition by flushing the ducts were not successful.

## System Trial

Two cable failures occurred last year in the vicinity of Halsted Street and 91st Street. Although the cable to manhole bottom voltages were satisfactory, it was found that the cable was slightly positive to ground in the ducts. The nearest substation was about one mile away, and the customary drainage connection appeared too costly. Furthermore, this substation was operated on a limited schedule. As a result of this, a cathodic protection system was proposed. A rectifier was mounted on a pole in a nearby alley. Twelve six-foot steel rods were driven into the ground about twenty feet apart in an adjacent vacant lot to be used as a temporary anode. They were connected to the positive terminal of the rectifier. The negative terminal was connected to the cables in the nearest manhole.

A trial of this system was announced at a meeting of the Joint Electrolysis Committee of Chicago and all interested parties were invited to witness the experiment.

## Effect on Signal System

The Chicago, Rock Island and Pacific Railroad tracks are about 280 feet north of this location. Signalmen from that railroad were asked to determine if their system was affected by the cathodic protec-

<sup>\*</sup>Submitted for publication November 7, 1955. A paper presented at a meeting of the Northeast Region, National Association of Corrosion Engineers, Niagara Falls, N. Y., November 3, 1955.

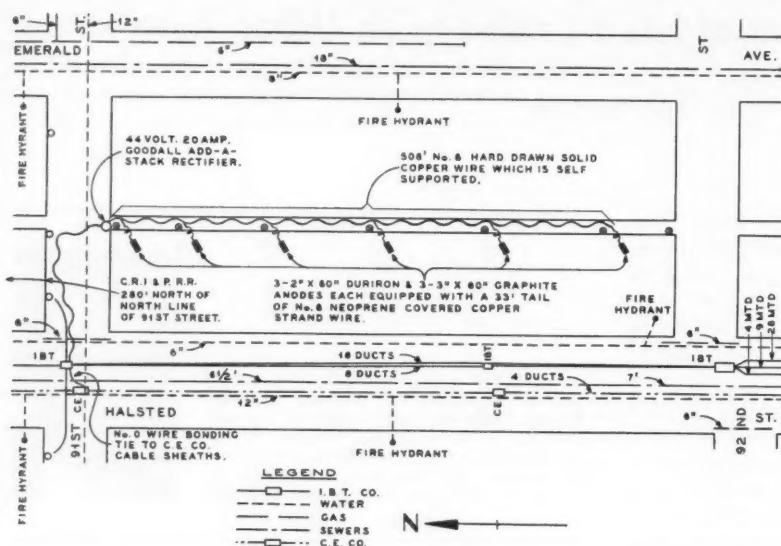


Figure 1—Cathodic protection system at 91st and Halsted Streets.

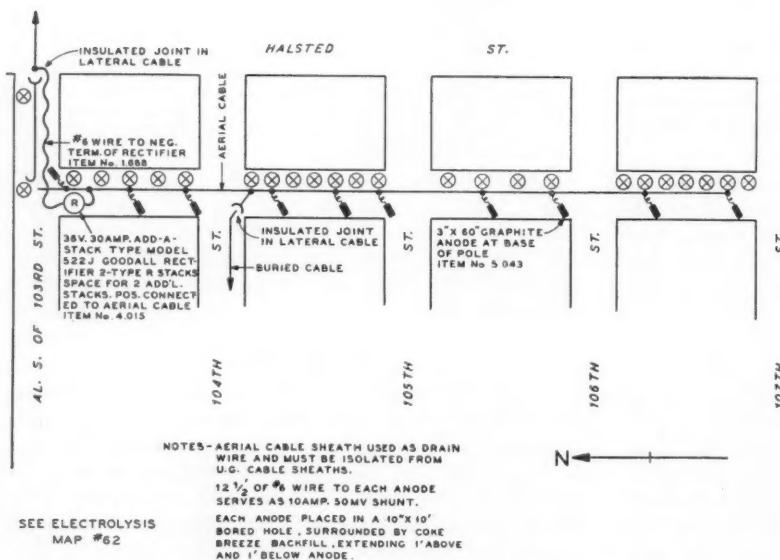


Figure 2—Cathodic protection system at 103rd and Halsted Streets.

tion system. With the rectifier delivering 11 amperes at 42 volts, voltage measurements were made for some distance along the rails. It was found that no undesirable effects had been produced on the railroad's signal system.

### Final Design

A layout of this cathodic protection system and the underground plants in the vicinity are shown in Figure 1. The driven rods were replaced by permanently placed anodes located at the base of each of six poles as shown. There are 26 telephone ducts in Halsted Street between 91st and 92nd Streets and 16 of these are occupied by cables.

By way of experiment use is being made of three Duriron and three graphite anodes. They are con-

nected by means of an aerial hard drawn copper wire which is self-supporting. It is insulated so that workmen may not be surprised by the voltage when they contact it and the aerial lead cable sheaths. The system now handles 7 amperes at 11 volts.

### Testing Other Underground Plants

There is a single power cable of the Commonwealth Edison Company paralleling and about ten feet away from the author's company's ducts. During the investigation, it was found that this power cable was slightly positive to ground even with the cathodic protection rectifier off. To prevent damage here, a No. 0 wire interconnects the power and telephone cables at 91st and Halsted Streets. In the preliminary tests only one ampere was required in this connection.

The water, gas and sewer system pipes were also located and shown on the chart. The author does not believe he has established a hazard with respect to any of these pipes (several tests have been made which bear this out). It should be noted that the gas pipes are in short sections only and probably are entirely safe. The water pipe in 91st Street is about forty feet from the nearest anode and it appeared likely that it might be affected. At a valve manhole near the street corner the pipe potentials were measured. With the rectifier delivering seven amperes, the pipe to iron rod ground voltage was  $-0.2$ . When the rectifier was off, this voltage was  $-0.1$ . Evidently, the anode system is raising the ground potential in this vicinity. There was no appreciable difference when the nearest anode was disconnected.

### Duct Anode Trial

In order to avoid entirely any hazard to other underground plants, the use of a duct anode was proposed. One of the cables which had failed was left in its duct and it was made positive with respect to the other cables. It was found that the cathodic protection did not extend more than the second cable in each direction from the anode. It therefore was not suitable for such a large duct formation and the idea was abandoned.

### Procedure

The establishment of this cathodic protection system involved the following steps:



1. A preliminary trial using driven rod grounds. (In some cases automobile batteries have been employed to supply the trial current.)
2. Notifying the Joint Electrolysis Committee of Chicago.
3. Inviting the railroad signal people to determine the effect on their plant.
4. Adjusting the current flow so that the cables are slightly negative to vacant duct slug.
5. Making a joint test with the Commonwealth Edison Company and providing for a tie to their plant.
6. Checking the presence of other underground plants (including test where possible).
7. Determining the power cost which is based on the output voltage and current divided by 60 percent for efficiency.

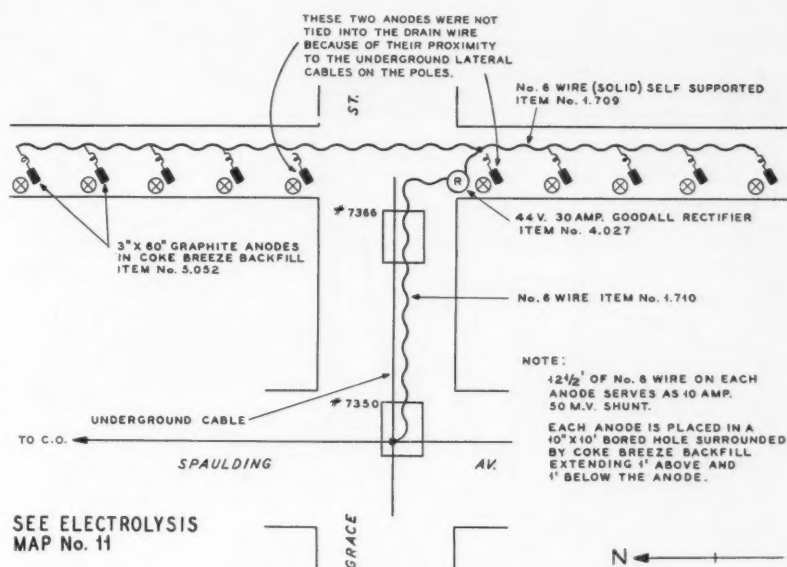


Figure 3—Cathodic protection system (Spaulding Avenue and Grace Street.)

#### Other Cathodic Protection Systems

Figure 2 shows the layout for one of Illinois Bell's largest cathodic protection systems. In this case a 36-inch water main in 104th Street caused the Halsted Street cables to be seriously positive. The water main provides a path of high conductivity toward a substation about  $1\frac{3}{4}$  miles away. To clear this hazard ten anodes were installed as shown in Figure 2. This system carries 21 amperes at 36 volts and protects about \$750,000 worth of telephone cables. In order to conveniently check the operation of the anodes, a quick measurement of the current to each anode is provided by marking off  $12\frac{1}{2}$  feet of No. 6 wire at each anode. With a voltmeter of 50 millivolt sensitivity connected across this section, the meter scale becomes 10 amperes. The total current and voltage is measured every month.

Figure 3 illustrates another large system employing ten buried anodes with an even larger rectifier. It delivers 22 amperes at 32 volts. On several of the figures, references are made to the method of making the ground bed. A machine is used to drill a 10-inch hole 10 feet deep and a fine dustlike coke is used to fill the space around the graphite or Duriron anode. The item numbers are shown only for record and accounting purposes.

Figure 4 shows a cathodic protection system having a similar ground bed anode. The system is different in that it protects two important cable routes which are one-half mile apart. Note in the lower left

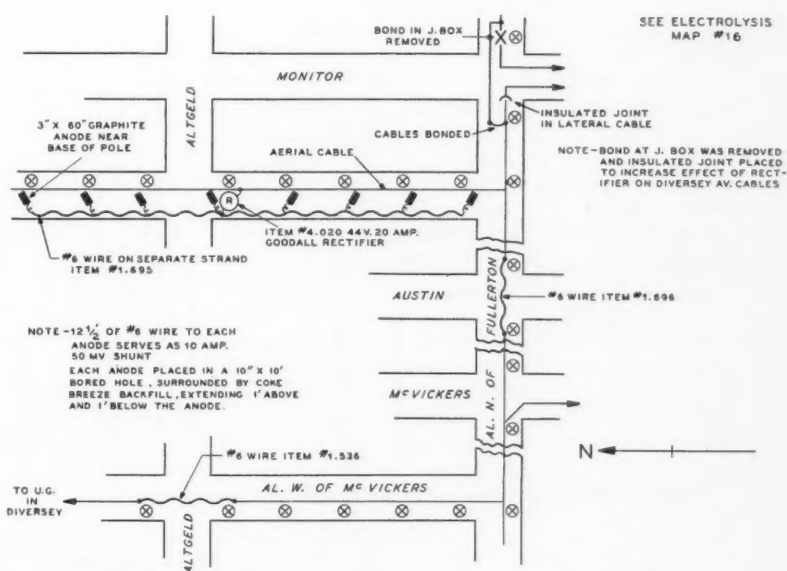


Figure 4—Cathodic protection system (Altgeld and Monitor Streets.)

part of Figure 4 that the aerial cables are joined by a No. 6 wire tie so that some of the protective current is thus received from Diversey Avenue.

#### Forced Drainage

Figure 5 shows a system which might be called Forced Drainage. The rectifier positive is connected to the railway structure rather than a ground bed, thus providing drainage without an unusually high investment in large conductors. The rectifier negative is connected to several underground cable sections either with direct connections or through resistors.

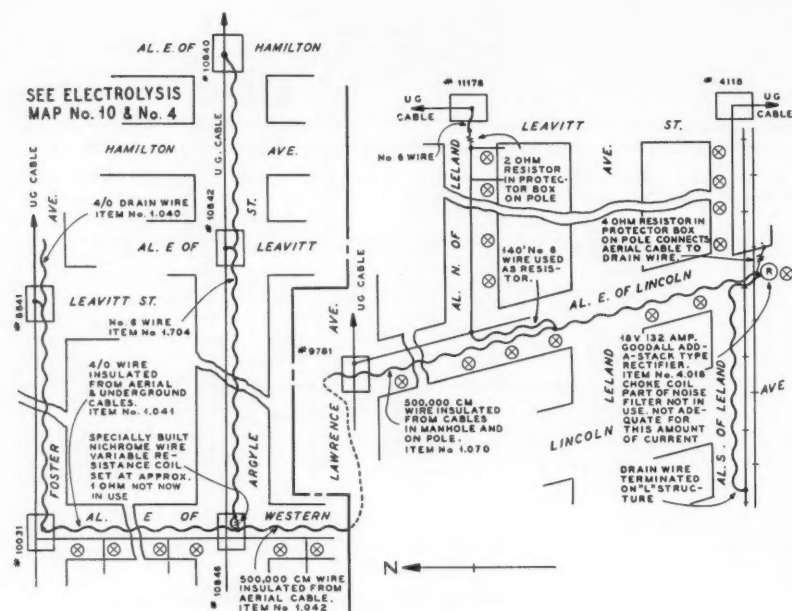


Figure 5—Map showing cathodic protection system at Lincoln and Leland Avenues.

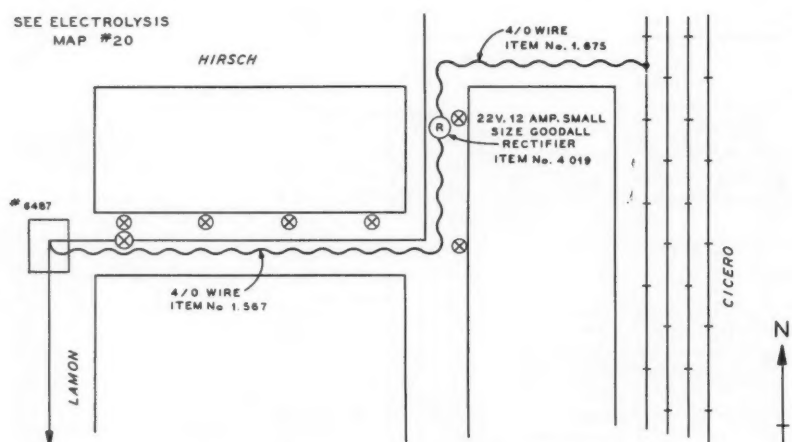


Figure 6—Cathodic protection system (Cicero and Hirsch Streets rectifier.)

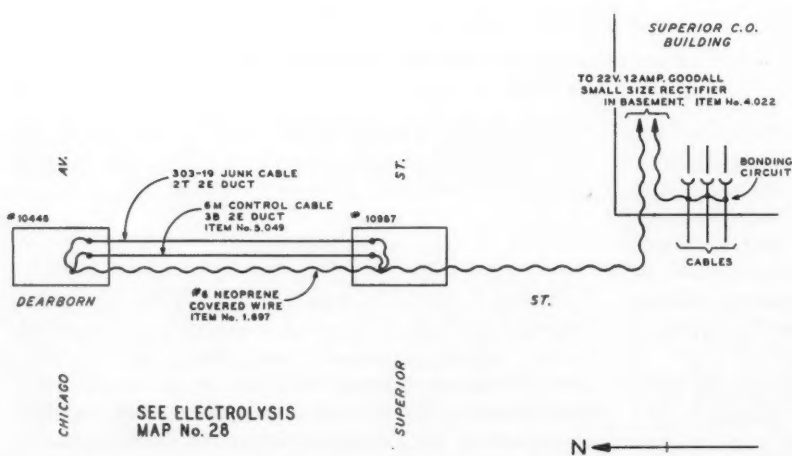


Figure 7—Duct anode system (Chicago Avenue and Dearborn Street).

The resistors are chosen to adjust the current flow from a particular cable branch to obtain proper conditions.

In the upper center of the figure a note indicates that 140 feet of No. 6 wire is used as one of the resistors. As previously mentioned, an effort has been made to obtain a cable to earth potential of  $-0.1$  volt or more on each branch. This is limited to minimize and prevent as far as possible disturbing the potentials of other underground plants.

In the center of the drawing note that a 500,000 CM cable is indicated. This is a part of the original drainage system which required low resistance. A forced drainage system does not require such good conductivity, because the rectifier can be easily adjusted to overcome the losses in a smaller wire. The rectifier in this system delivers 110 amperes at  $9\frac{1}{2}$  volts. The monthly power bill is \$23.50. The rectifier includes an inductor and capacitor filter to eliminate the harmonics which have caused noise on the telephone circuits within the cable. It is standard practice to order filters for all new installations.

Figure 6 shows another forced drainage system which drives current from cables to the streetcar rails. It operates with 2 amperes at 2 volts and the power cost is a minimum \$1.00 per month. The wire is 679 feet long and 4/0 size although it could well have been No. 6 if the system were a new installation rather than a modified one.

Figures 7 and 8 show the use of duct anodes which Illinois Bell would like to use more generally so as to avoid possible damage to neighboring underground plants. The protected section shown in Figure 7 is 374 feet long. It includes 32 ducts with 16 cables.

### Control Cable

In order to spread the protective current, use is being made of a junk cable and a control cable. A control cable is made of Neoprene insulated steel strand which is covered with a  $\frac{1}{2}$  inch layer of lead. Unfortunately this device corrodes rather rapidly. The corrosion prod-

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ucts are highly conductive and tend to clog the ducts. When they fill the cavities between ducts they cause short circuits, or at least "hot spots," where the current is concentrated. This in effect reduces or even nullifies the protection for the rest of the section.

To reduce these "hot spots" and duct clogging, the control cable is moved a few inches every six months. Because the most hazardous section is only about 30 feet long, it was proposed to install graphite rods in some of the spare ducts and to use them as control anodes. They were not suitable, however, because of a bend in the ducts. The smaller Duriron anodes may be employed. One difficulty experienced with duct anodes is that the protective current does not distribute to the more remote cables in a large duct formation.

Figure 8 illustrates one of the more difficult problems encountered by the author. There are 47 ducts in a formation built along the side of a tunnel which passes under the Chicago River at LaSalle Street. The present control cable is shown in the most suitably located spare duct available. Forty-two of the ducts are occupied by cables including the control cable and four which are so damaged that they cannot be withdrawn. (The cause of this damage is not known although it is believed to be a mechanical difficulty.) Tests in two other spare ducts indicate that sufficient protective current does not reach the upper cables.

Other companies have noted that the life of cables apparently is extended by lowering their potential without achieving negative potentials. This seems to have happened here. In this case the author has had

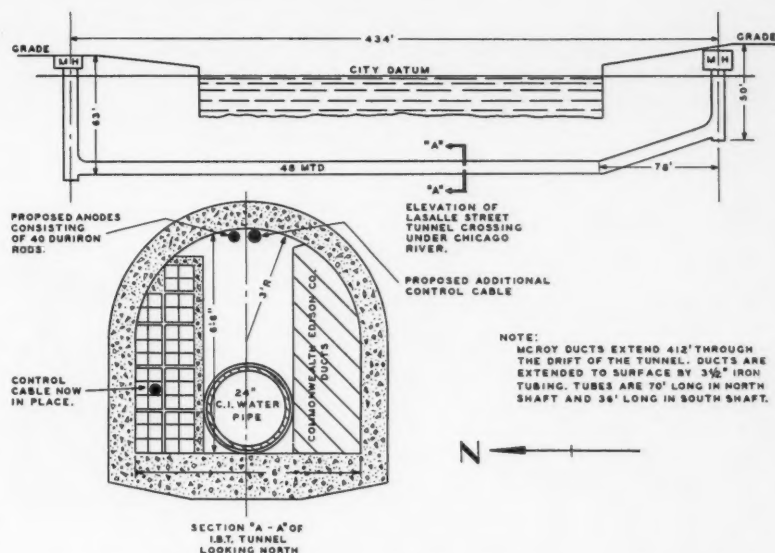


Figure 8—Tunnel cathodic protection system (Chicago River tunnel crossing at LaSalle Street).

difficulty in shifting the control cable and has found "hot spots" in the duct surveys.

Consideration is being given to mounting anodes near the top of the tunnel as shown in the cross section. The proposed control cable shown with the anodes is one which was ordered to replace the original duct anode. The Duriron anodes will be connected by individual wires to the tunnel head where they will connect to the rectifier. The Edison cables are jacketed because they also experienced trouble in this tunnel. Some of their cables have a lead covering over the jackets. Therefore, they have been connected into Illinois Bell's cathodic system to protect them.

So far as tests have indicated, the cast iron water pipe has not been affected. The main section is made up of McRoy ducts which are of vitrified clay. The tunnel ends, however, are made up of iron pipes which would short circuit the control cable if it extended beyond the clay ducts.

**Any discussions of this article not published above will appear in the December, 1956 issue.**



# Fundamentals of Liquid Metal Corrosion\*

By W. D. MANLY

## Introduction

**C**ORROSION HAS been defined by U. R. Evans<sup>1</sup> as follows: "The word corrosion denotes the destruction of metal by chemical or electrochemical action; a familiar example is the rusting of iron." Thus, corrosion by his definition denotes the transfer of electrons. But this is not usually the case in liquid metal attack. To define the destruction of a solid metal by a liquid metal as corrosion, this definition must therefore be broadened to allow for the solution or solubility of a solid metal in a liquid metal wherein no transfer of electrons is involved.

Liquid metal corrosion depends for the most part simply on the solution rate and the extent of solubility of the solid metal in the liquid metal. It should be noted, however, that many complicating factors can influence the solution rate or the attainment of the solubility limit. The formation of surface intermetallic compounds and oxide or nitride films are good examples of such factors. In addition mention might be made of impurities in the liquid metals which can increase the solution rate. Still other factors are temperature gradients and multimetallic systems which can cause an increase in the amount of attack over that expected to saturate the liquid metal because of the mass transfer of material under the driving force of the temperature gradient or the concentration gradient.

In the short time that interest has existed in the corrosion characteristics of liquid metals, many testing methods have been developed to determine the interaction between liquid metals and solid metals. These methods range from the very simple static capsule test to the expensive and complicated forced circulation loop tests which carefully reproduce the operating conditions. The tests and the manner in which data are derived from them have been described previously.<sup>2,3,4</sup>

Several types of corrosive attack of solid metals by liquid metals have been observed.<sup>5</sup> In this discussion the types of liquid metal attack will be arranged into the following categories:

1. Simple solution.
2. Alloying between liquid metal and solid metal.
3. Intergranular penetration.
4. Impurity reactions.
5. Temperature gradient mass transfer.
6. Concentration gradient mass transfer, or dissimilar metal mass transfer.

Examples of all six kinds of liquid metal corrosion will be presented and described in detail in subsequent paragraphs.

Several variables affecting liquid metal corrosion must be considered. These factors are:



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## Abstract

The corrosion of structural metals in liquid metals is for the most part the result of solubility of the various constituents of the metal or alloy in the liquid metal. The manner in which this solution manifests itself gives rise to many types of attack, ranging from a simple solution type attack to a deep intergranular attack with the preferential leaching of one constituent of an alloy. Examples of the many types of corrosion experienced with solid metal-liquid metal systems are illustrated. The role of impurities on the corrosion is discussed.

In addition to the solution stage, which would soon disappear in a static one metal system on reaching a solubility limit, the corrosion of metals can be continued through the removal of materials from solution in the liquid metal with a temperature gradient or by dissimilar metal transfer. The transfer of metal in a plumbing system by the mechanisms of mass transfer—temperature gradient and dissimilar—will greatly increase the amount of corrosion as compared to the results obtained in static systems. Examples of temperature gradient mass transfer and dissimilar metal transfer are reviewed, and factors governing the occurrence of these phenomena are outlined. 4.7

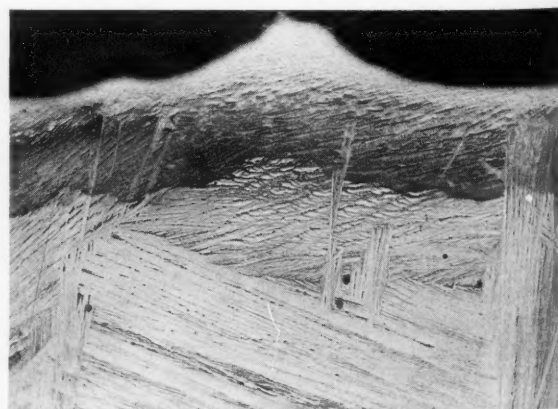


Figure 1—Even surface removal from titanium specimen after 40 hours in lead at 1000 C. 53X.

\* A paper presented at the Eleventh Annual Conference, National Association of Corrosion Engineers, Chicago, Illinois, March 7-11, 1955.

1. Temperature.
2. Temperature gradient.
3. Cyclic temperature fluctuation.
4. Surface area to volume ratio.
5. Purity of liquid metal.
6. Flow velocity or Reynolds number.
7. Surface condition of container material.
8. Number of materials in contact with the same liquid metal.
9. Condition of the container material (the presence of a grain boundary precipitate, the presence of a second phase, the state of stress of the metal and the grain size.)

### Temperature

Temperature is one of the most important variables, because the higher the temperature the higher the solubility of the solid metal in the liquid metal. Also, as the temperature increases, diffusion rates increase. This is a matter which is quite important in certain types of liquid metal corrosion.

When a temperature gradient exists in a liquid metal system, the difference in solubility of the dissolved metal in the liquid metal in the hot and cold parts of the system gives rise to temperature gradient mass transfer.

The cyclic temperature fluctuation is helpful in explaining erroneous static corrosion results since in a supposedly isothermal condition in a poorly controlled furnace the liquid metal-solid metal interface temperature can fluctuate quite appreciably around a mean temperature. Thus, at the high temperature, material goes into solution and subsequently at the lower temperature comes out of solution and precipitates in the bulk liquid, or forms dendrites, or forms a uniform layer on the container wall. The Cu-Bi system is an example of this: at  $500 \pm 5^\circ\text{C}$  the corrosion rate is several times greater than that at  $500 \pm 0.5^\circ\text{C}$ .

The ratio of surface area of the solid metal to the volume of liquid metal is a controlling factor in the amount of corrosion experienced in a solid metal container in a static system inasmuch as the metal will corrode sufficiently to saturate the liquid metal at the operating temperature. Therefore, as the ratio of the surface area to volume decreases, the amount of corrosion increases.

Purity of the liquid metal can have quite an effect on the rate at which the solubility limit is reached and can markedly affect the wetting tendency of the liquid metal on the solid metal.

### Flow Velocity

The flow velocity, or Reynolds number, is important in a forced circulation pump loop only in that a decrease in the thickness of the lamellar layer in the hot and cold legs occurs as the flow velocity increases. Thus, when metal atoms pass from the hot leg to the cold leg, the diffusion paths are shorter in these two regions.

The surface condition of the container material is not a particularly important variable so long as it is free of surface films. After equilibrium is reached

between the liquid metal and the solid metal, the surface condition should have no effect. Its primary effect then would be to change the rate at which the liquid metal is saturated. The greater the surface area that is exposed, the faster the liquid would become saturated.

When two or more solid metals are in contact with a liquid metal, the phenomenon of dissimilar metal mass transfer, or concentration mass transfer, should be considered even when the temperature is constant. Equilibrium is attained in a multicomponent, multiphase system only when the chemical potential of each component in any given phase is equal to its chemical potential in every other phase. A redistribution of the components between the phases of the system therefore will tend to occur until the condition of the equality of the chemical potentials is satisfied. The driving force for this process, thus, is associated with the equalization of the chemical potentials which results in a decrease of the free energy of the system.

The condition of the container material, with respect to grain size and other variables must be considered because the wettability of individual grains are different from the wettability of grain boundaries. A continuous carbide or oxide network at the grain boundary can greatly increase the corrosion that will be experienced.

In all liquid metal corrosion tests, these variables must be considered and controlled to obtain information that will be useful in the over-all understanding of the suitability of solid metals as containers for various liquid metals.

The first example of liquid metal corrosion to be discussed is simple solution-type attack. In the case of a pure metal, an example of the even removal of metal from the surface to saturate the liquid metal is illustrated in Figure 1 which shows the surface of a titanium specimen after being exposed to lead at  $1000^\circ\text{C}$  for 40 hours. In the case of a complex alloy the attack also can be a simple solution type. An example of this is shown in Figure 2 which illustrates the corrosion of Type 304 low carbon stainless steel in sodium after 40 hours at  $1000^\circ\text{C}$ .

If all the phase diagrams of liquid metal-solid metal systems were available, one could ascertain the depth of attack that would occur in a static system as a result of simple solution by examining the solubility limit of the solid metal in the liquid metal at the operating temperature. One would have no conception, however, of the rate at which the solubility limit was achieved. Thus, after examining the Fe-Li phase diagram one would expect that the amount of attack of iron by lithium should be quite small in a static, isothermal system. Corrosion tests have confirmed this. Therefore, in simple solution type attack the amount of damage the solid metal will receive depends on the ratio of metallic surface area to liquid volume of the system, but the rate at which the attack occurs can be influenced greatly by other variables, such as impurities in the system.

### Alloying of Liquid and Solid Metals

The next type of corrosion to be discussed is the alloying that occurs between liquid metals and solid

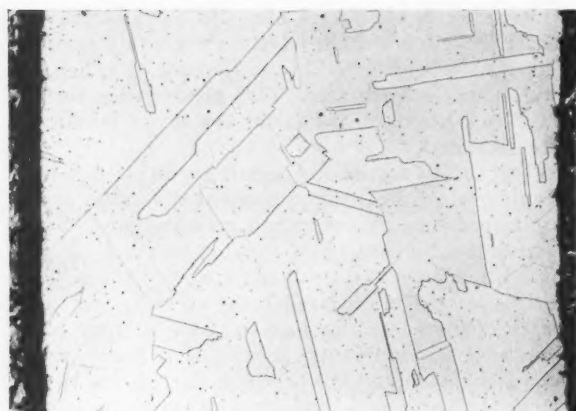


Figure 2—Attack of Type 304 low-carbon stainless steel after 40 hours by sodium at 1000 C. 40X.

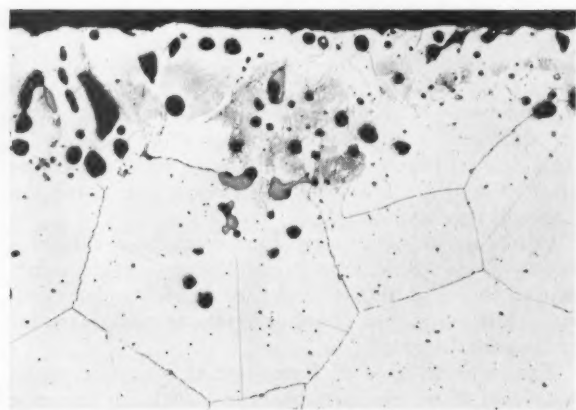


Figure 4—Type 446 stainless steel tested for 400 hours in lead at 1000 C. Note compound formed at grain boundaries and transformation caused by removal of nickel. 106X.

metals. For this to result, there must be some solubility of the liquid metal in the solid metal. In some experiments the liquid metal dissolves considerably in the solid metal with the formation of an intermetallic compound. When vanadium is tested for 400 hours in lead at 1000 C, an intermetallic compound is formed between the vanadium and lead, as can be seen in Figure 3. When Type 446 stainless steel is tested in lead at 1000 C, it is found that after 400 hours lead has diffused into the alloy predominantly at the grain boundaries and has formed a compound (Figure 4). Sodium will penetrate solid copper at the grain boundaries and will form an intermetallic compound, which is considerably harder than the base metal, copper, as illustrated in Figure 5.

One of the more serious types of corrosion that can occur is the deep intergranular penetration brought about by the selective removal of one constituent from an alloy. The best example of this is the selective removal of nickel from austenitic stainless steels. Figure 6 shows a Type 304 low carbon stainless steel after 400 hours of testing in lead at 1000 C.

Another example of this type of corrosion is given in Figure 7, which illustrates the attack on Type 304 low carbon stainless steel after 400 hours in lithium at 1000 C. A considerable portion of the attack is

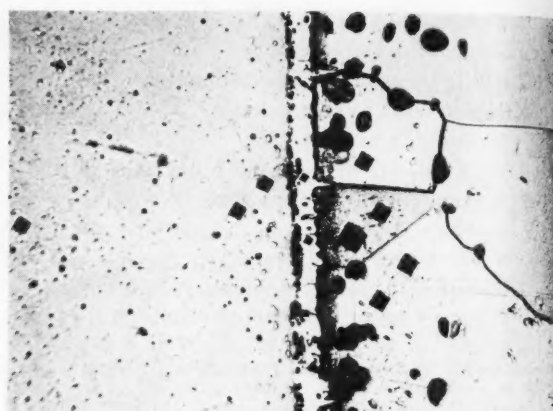


Figure 3—Vanadium (at left) tested for 400 hours in lead at 1000 C. The formation of an intermetallic compound is shown. Note Vickers hardness impressions, denoting relative hardness of the V-Pb compound. 106X.

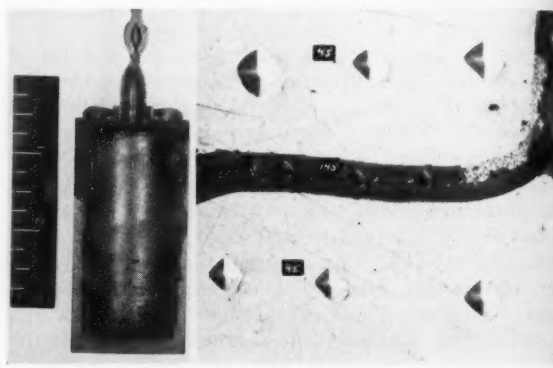


Figure 5—Sodium penetration into solid copper at the grain boundaries with the resultant formation of an intermetallic compound. Copper capsule—sodium test was made at 1800 F for 100 hours.

attributed to the removal of nickel caused by the alloying of the nickel with the iron container wall. It is assumed that the attack would have been less severe if the specimens and containers had been of the same material. The selective removal of nickel from a 75 percent Ni-25 percent Mo alloy also occurred in a sample from the hot leg of a thermal convection loop which operated for 200 hours with lead at 800 C and with a 300 C temperature gradient (Figure 8). In this case the nickel was preferentially removed from the hot zone and deposited in the cold zone of the loop.

In liquid metals, impurities such as oxygen, nitrogen, and carbon, can have an appreciable effect upon the rate of attack. In some cases the whole mode of attack can be changed because of the effect of the impurity on the surface tension or because of the reactivity of the impurity. An example of this is to be found in the attack of stainless steels by lithium when nitrogen is the principal contaminant.

Figure 9 illustrates the shallow attack produced by pure lithium at 800 C in 100 hours on Type 316 stainless steel. But if the lithium is contaminated with a small quantity of nitrogen, the complete tube wall, comprising 0.035 inch, will be penetrated by the lithium during the same type of test. This is caused



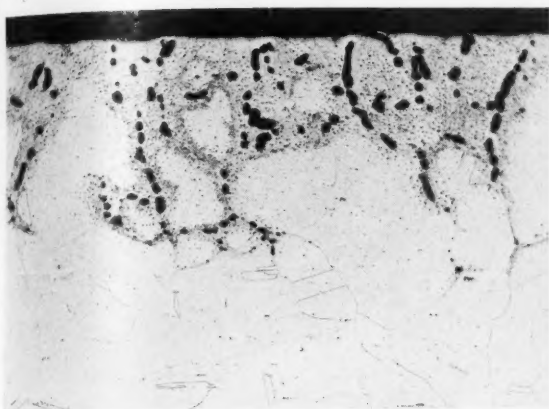


Figure 6—Type 304 low-carbon stainless steel after 400 hours in lead at 1000 C. Note the selective removal of nickel from the alloy, which brought about a phase transformation. 53X.

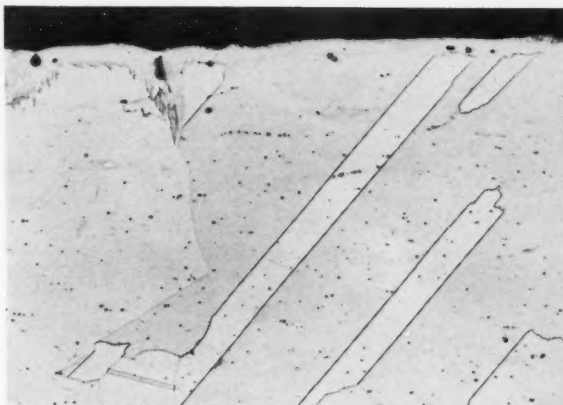


Figure 9—Very shallow attack produced by pure lithium at 800 C in 100 hours on Type 316 stainless steel. 132X.

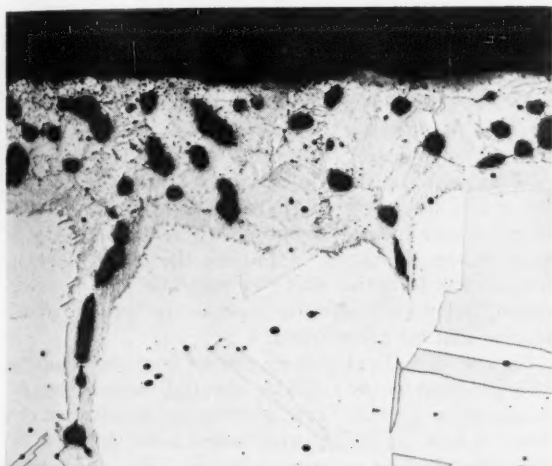


Figure 7—Type 304 low-carbon stainless steel after 400 hours in lithium at 1000 C. Note the selective removal of nickel from the alloy, which brought about a phase transformation. 155X.

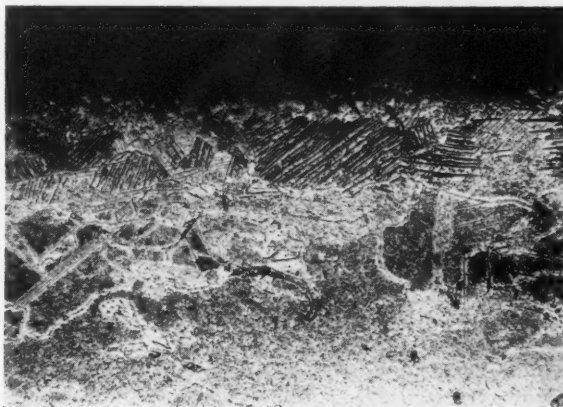


Figure 10—Heavy carburization after long-time service of Type 347 stainless steel by sodium contaminated with carbon. 135X.

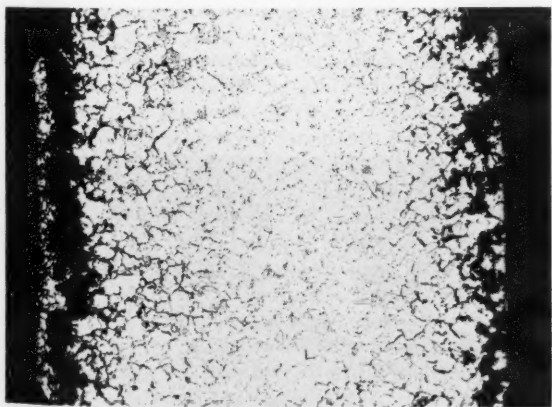


Figure 8—Hot leg of a 75 percent nickel—25 percent molybdenum thermal convection loop operated for 200 hours with lead at 800 C and with a temperature gradient of 300 C. 82X.

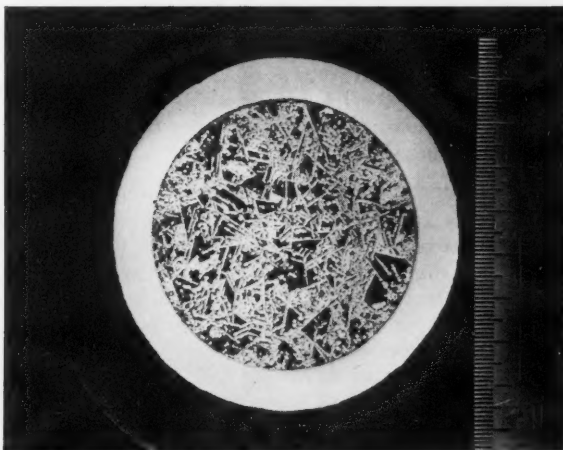


Figure 11—Cross section cut through the pipe wall depicting a plug from a Croloy steel thermal convection loop that operated for 200 hours at 800 C with a temperature gradient of 200 C. These crystals were primarily alpha iron.

by lithium nitride reaction with the carbides that form the grain boundary network, since a test in Type 316 stainless steel with lithium that was contaminated with nitrogen resulted in shallow attack

when the testing temperature was above the solution temperature of the carbides.

High temperature alloys can be severely carburized by liquid metals, especially sodium and lithium, if the liquid metals have been stored under kerosene or have acquired carbonaceous material from some

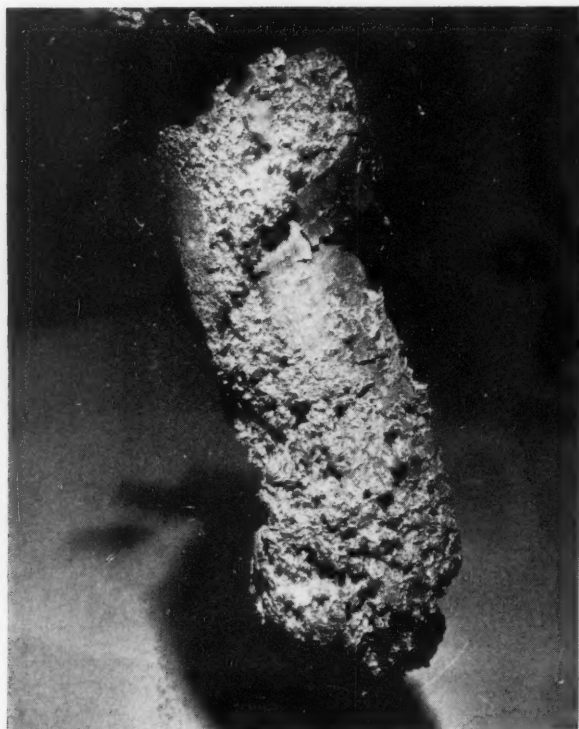


Figure 12—Plug from an Inconel-Pb thermal convection loop that operated for 125 hours at 800 C with a temperature gradient of 200 C. 3.5X.

other source. The carburization, after a long service period, of Type 347 stainless steel by sodium contaminated with carbon is shown in Figure 10. In corrosion by sodium, oxygen impurities can have an appreciable effect on the rate at which the solubility limit is attained. In lead the oxygen contamination, if anything, decreases the rate of corrosion inasmuch as most of the constituents of high temperature alloys can reduce the lead oxide and form a film that will act as a diffusion barrier between the solid metal and the liquid.

#### Temperature Gradient Mass Transfer

The most damaging type of liquid metal corrosion is temperature gradient mass transfer. The even removal of a slight amount of a container wall will not adversely affect its load carrying abilities; however, the collection of this material in the colder regions of heat exchanger tubes as dendritic crystals would cause a cessation of flow.

An example of mass transferred material is seen in Figure 11, which is a plug from a Type 446 stainless steel thermal convection loop that operated 200 hours at 800 C with a temperature gradient of 200 C. These crystals were primarily alpha iron.

Another example is the massive mat of mass transferred material shown in Figure 12, which is a plug from an Inconel-Pb thermal convection loop that operated for 125 hours at 800 C. In some loop experiments the crystals do not grow from nuclei in the bulk liquid. Instead mass transferred material nucleates on the wall and the crystals grow out into the stream as revealed in Figure 13 (a photograph of iron crys-

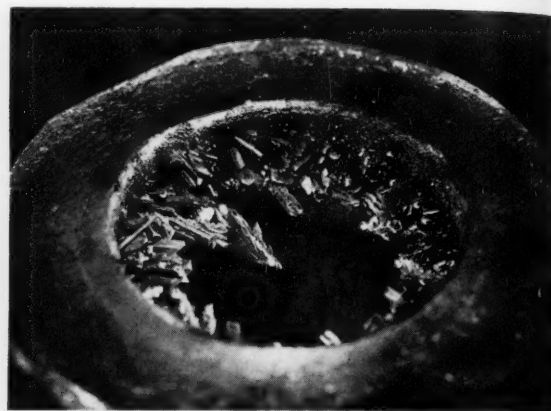


Figure 13—Iron crystals formed in a Type 410 stainless steel thermal convection loop after 40 hours operation with lithium at 1000 C.

tals formed on a Type 410 stainless steel thermal convection loop after 40 hours at 1000 C with lithium.) The driving force for temperature gradient mass transfer is the difference in solubility of the dissolved metal in the liquid metal at the temperature extremes of the heat transfer system.

In examining the Cu-Pb phase diagram (Figure 14), it can be seen that there is considerable solubility of copper in lead at 900 C, whereas at 500 C it is much lower. Thus, by examining the phase diagram, the driving force for this phenomenon can be determined, but no information concerning the rate of the process can be determined.

Figure 15 indicates the various steps in temperature gradient mass transfer through which metallic atoms must go. If there is selective removal of one element from an alloy, these atoms must diffuse to the surface and then go into solution. The atoms must then diffuse through the lamellar layer into the bulk liquid stream and finally be carried to the cold portion of the system where supersaturation will occur. A collection of such atoms can accumulate and form a nucleus that will grow to a stable size and then drop from the liquid. On the other hand, the atom may supersaturate close to the wall, diffuse through the lamellar layer, and then nucleate on the metallic wall and form a dendritic crystal or diffuse into the wall. As yet, the rate controlling step in temperature gradient mass transfer has not been found.

To obtain more data on mass transfer in liquid lead, a series of quartz thermal convection loops were operated with various alloys and the elements comprising the alloys.<sup>6</sup> Results of these tests have indicated that the rate controlling step for mass transfer by lead at the velocities used in the thermal convection loop is probably the solution step in the hot leg. For example, it was found that the formation of an intermetallic compound, or other type of diffusion barrier, in the hot zone greatly increases the time that elapses before a plug occurs in the loop.<sup>7</sup>

#### Dissimilar Metal Mass Transfer

The last type of liquid metal corrosion to be discussed is dissimilar metal mass transfer or concentration gradient mass transfer. The best example

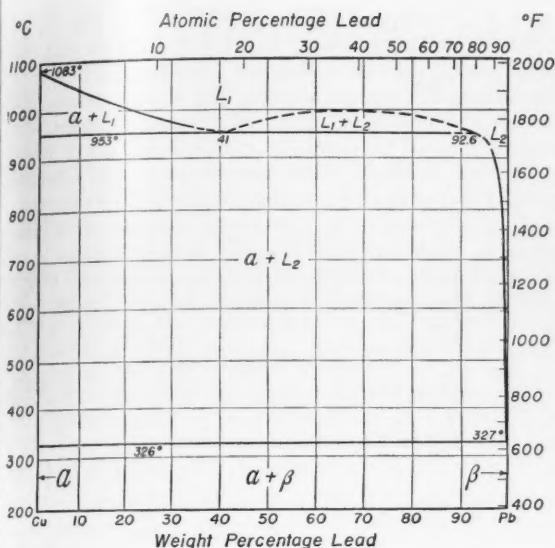


Figure 14—Copper-lead phase diagram.

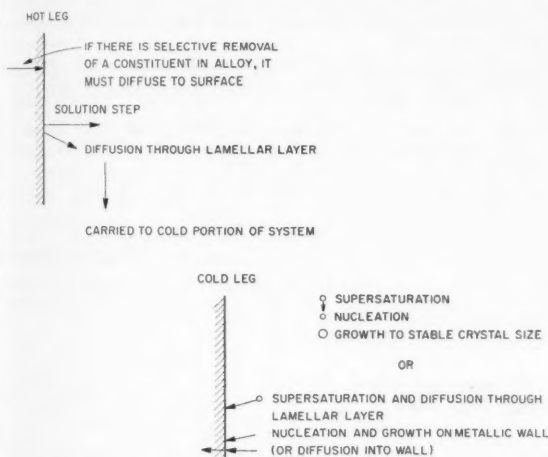


Figure 15—Various steps through which metallic atoms must go in temperature gradient mass transfer.

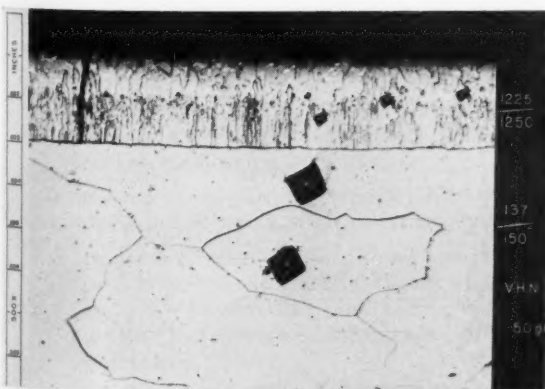


Figure 16—Interdiffusion between molybdenum and nickel by dissimilar mass transfer after 100 hours at 1000 C. Vickers hardness impressions indicate relative hardness of the nickel-molybdenum alloy. 250X.

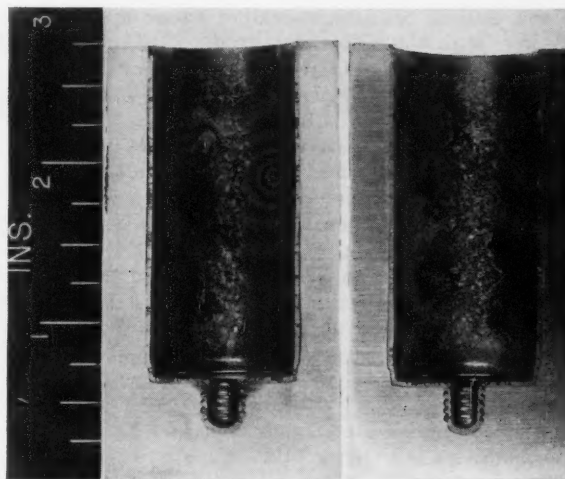


Figure 17—Dissimilar mass transfer that occurred between lump silicon and the iron capsule. The silicon went into solution and was carried to the wall, came out of solution and alloyed with the iron capsule to form a Fe-Si alloy. Test was made at 1000 C for four hours. Content was approximately 25 percent Si, 75 percent Li.

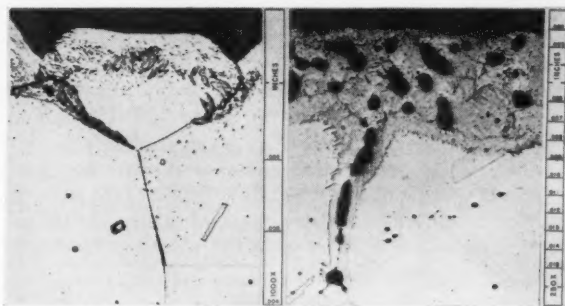


Figure 18—The effect of type of container on the corrosion of Type 304 stainless steel in lithium. Test was made at 100 C for 400 hours. Photograph at left is for Type 304 stainless steel container and photograph on right is for iron container.

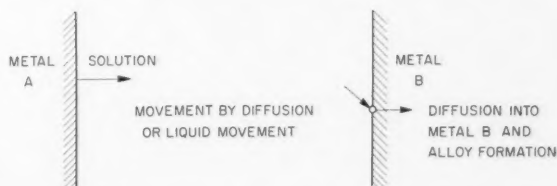


Figure 19—Schematic view of the manner in which dissimilar metal mass transfer occurs.

that has been obtained at the Oak Ridge National Laboratory is the interdiffusion between molybdenum and nickel (Figure 16). In this case the molybdenum sample was being tested in sodium contained in a nickel crucible. After 100 hours at 1000 C a sufficient quantity of nickel had transferred through the sodium and deposited and alloyed on the molybdenum surface to produce the Ni-Mo intermetallic compound and solid solution.

Another example of this phenomenon resulted in the course of testing lump silicon with lithium in an iron capsule. Figure 17 shows that all the silicon has gone into solution in the lithium and has been carried



to the wall of the iron container where alloying of the iron with the silicon occurred.

Dissimilar metal transfer can cause many misleading results as can be seen in Figure 18 which illustrates the difference in the depth of corrosion when Type 304 stainless steel was tested with lithium in two types of containers. In one case the Type 304 stainless steel specimen was placed in a Type 304 stainless steel container, and the attack was rather shallow. In the second case the Type 304 stainless steel was tested in an iron container and the attack was much more severe. This situation came about because of the selective removal of nickel that was transported to the iron wall where alloying of nickel with iron occurred, allowing the corrosion process to continue.

A schematic view of the manner in which dissimilar metal mass transfer takes place is seen in Figure 19. In this case atoms of metal A go into solution and move to the surface of metal B either by diffusion and/or by movement of the liquid. When they reach the surface of metal B, they come out of solution, alloy with metal B, and diffuse inward. The driving force for dissimilar metal transfer is the decrease in the free energy that is achieved through the alloying of the two metals.

The larger the difference between the chemical potentials of A and B in the two solid phases, the greater will be the driving force for the occurrence of mass transfer. The rate of mass transfer is dependent on the temperature inasmuch as an increase in temperature will increase the diffusion rate in both the liquid and the solid phases. A high solubility of metal A in B (or B in A or both) also will facilitate this type of mass transfer.

#### Conclusion

Liquid metal corrosion has been described as

mainly the solution of the solid metal in the liquid metal. The rate controlling step for the various types of liquid metal corrosion has not been determined. For the successful containment of the liquid metals, the amounts of impurities, such as oxygen, nitrogen, and carbon, should be carefully controlled. Future work in the field of liquid metal corrosion must be directed toward increasing the understanding of the rate controlling steps of dissimilar metal transfer, and temperature gradient mass transfer. When this has been accomplished, corrective measures can then be taken to keep these types of corrosion to a minimum.

#### Acknowledgments

The author acknowledges the assistance of John V. Cathcart, E. E. Hoffman, and other members of the Oak Ridge National Laboratory working in the field of liquid metal corrosion. The metallographical work used in this paper was performed by a group under the direction of R. J. Gray.

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*Any discussions of this article not published above  
will appear in the December, 1956 issue*

# The Effect of Iron in Galvanic Zinc Anodes in Sea Water\*

By R. B. TEEL and D. B. ANDERSON

## Introduction

**ZINC'S HISTORY** as a galvanic anode in sea water dates back to 1824 when Sir Humphrey Davy<sup>1</sup> advised the British Admiralty to attach blocks of zinc to the hulls of copper sheathed ships in order to retard the corrosion of the copper and thereby extend the service life of the ships. This early practice of preventive maintenance was extended further to buoys, moorings and eventually to the hulls of steel ships.

Though this practice has been carried along to the present day, the value of zinc as a protective anode for the underwater protection of a ship's hull has been under question for some time. Use of these anodes until the present day probably has been based on tradition rather than on engineering facts.

While the literature contains many references to the use of zinc as an anode in sea water,<sup>2,3,4</sup> its efficacy does not seem to have been seriously questioned until the early 1940's. (Reference 2, pp. 26-28.) About this time both the British Admiralty and the U. S. Navy conducted independent investigations on the behavior of zinc galvanic anodes in sea water. Their findings, which have been reviewed extensively by Schuldiner,<sup>2</sup> led to the following observations and conclusions:

1. The current output of zinc anodes in sea water is restricted, after a short period of time, by the formation of tightly adherent corrosion product films.
2. Corrosion product films have a high electrical resistance.
3. The electrical resistance of the corrosion product films and their rate of build-up is dependent upon the anodic current density. A high film resistance is associated with a low current density and vice versa.

Later studies made by a number of independent investigators and others<sup>2</sup> (ref 100-106), 5, 6 & 7 led to the following observations:

1. The decrease in the current output of zinc galvanic anodes was caused by the corrosion product build-up on their surface.
2. In some cases, the corrosion product film was adherent and had a high electrical resistance.
3. Special high grade<sup>(1)</sup> zinc (99.99 percent Zn) was a better anode material than high grade<sup>(1)</sup> zinc (99.9 percent Zn), and both were better anodes than intermediate grade zinc (99.6 percent Zn).
4. The minor impurities in zinc appeared to be



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## Abstract

Sharp decreases in the current output of zinc galvanic anodes in sea water are attributed to the increase in the electrical resistance and tenacity of the corrosion product films which form on the anode's surface. This behavior is influenced largely by the amount of iron present as a minor impurity in the zinc. Iron content should be kept below .0015 percent for best results. Zinc containing a higher iron concentration will develop a high resistance corrosion product film which will render the zinc less effective as an anode material. 5.2.2

responsible for the decrease in current output of zinc galvanic anodes. Lead, cadmium and iron were suspected as being responsible for this. In one investigation, it was suggested that the iron content be limited to .01 percent maximum.

Subsequent long term tests of heat exchangers fitted with special high grade zinc anodes revealed that a specification for special high grade zinc would not alone assure effective zinc anodes for sea water service. Further tests on cast and rolled zinc with various surface preparations, such as ground or chemically cleaned, eliminated these factors as the primary source of difficulty. Therefore, an intensive investigation of the chemistry of zinc galvanic anodes was

\*Submitted for publication May 2, 1956.

(1) ASTM Specification B6-49.

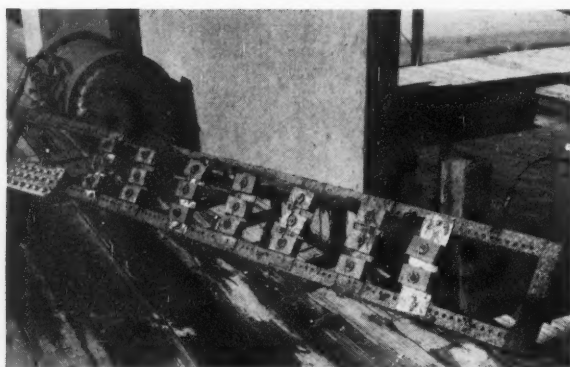


Figure 1—Immersion test rack with attached zinc specimens as used in early tests at Harbor Island. Current measuring resistors are at left. Photograph was taken at end of test.

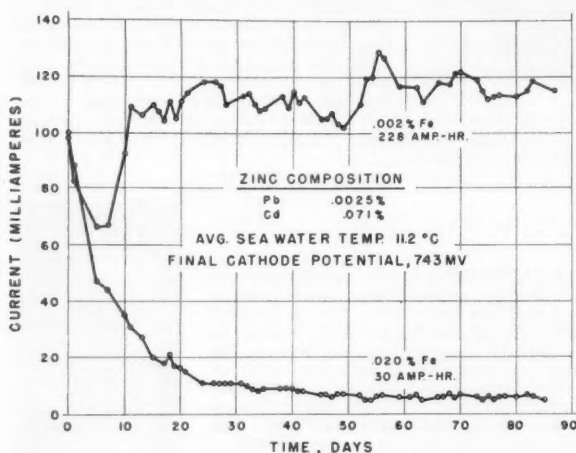


Figure 2—The effect of iron in galvanic zinc anodes in sea water with common cathode.

initiated in a series of tests in sea water at Harbor Island, N. C.

### Early Tests

Previous tests indicated that small scale laboratory tests were not suitable for this type of investigation. Therefore, zinc specimens measuring  $3\frac{3}{8}$ -inch x  $2\frac{3}{8}$ -inch x  $\frac{1}{2}$ -inch, having an exposed surface area of 22.2 square inches, were used in all subsequent tests. Experience indicated that galvanic couples of zinc and steel in open sea water would provide the best means for comparing zinc anodes of various compositions. Tests showed that considerable information could be gained by working the zinc specimens against a steel cathode which was common to all of the test zincs and which was sufficiently large in area to minimize cathodic polarization. This cathode was a large submerged steel tank which served as a screen tank for pump intake lines. All work was conducted in clean sea water, and the flow conditions were tidal with velocities in the range of 1-2 feet per second.

Included in the test circuit were 20 zinc anodes  $3\frac{3}{8}$ -inch x  $2\frac{3}{8}$ -inch x  $\frac{1}{2}$ -inch, each having an exposed area of 22.2 square inches. The large steel tank which served as a cathode was of indeterminate surface

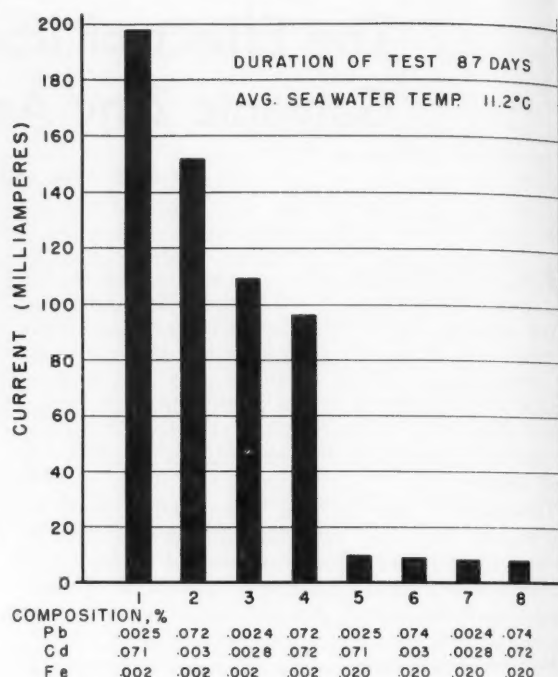


Figure 3—The current output of zinc specimens working separately against a submerged steel tank on the last day of test.

area. The arrangement of the zinc specimens on the sea water immersion test rack is shown in Figure 1.

Each specimen was bonded to the steel tank through a low resistance insulated wire and a 1.0 ohm current measuring precision resistor. A daily potential drop reading across each resistor was taken during the test period. These values were converted to current by Ohm's law in order to establish the relative current output characteristics of the various grades of zinc under study. It was thought at this time that the submerged steel tank would be of sufficient size to minimize cathodic polarization. However, its potential change of 120 mv was considered appreciable and it undoubtedly imposed some limit on the current output of the test zincs. It is reasonable to expect that the decrease in the current output of the two grades of zinc shown in Figure 2 during the first several days of test was due largely to polarization effects. Inasmuch as the cathode was common to all zincs, a decrease in the current output of the poorer grade of zinc (the one containing .020 percent Fe) would presumably be balanced to a degree by an increased current output of the better grade of zinc (the one containing .002 Fe). This effect, as well as the very drastic effect of iron on the current output of zinc, is shown in Figure 2.

All zincs were disconnected from the steel tank at the end of the test period. Then each zinc was connected to the tank separately so that its current output against the steel cathode could be determined. These results, which again show the restrictive effect of iron, are given in Figure 3.

The results of this test indicated the desirability of conducting a test on zincs in which the lead and cadmium content was held constant at a very low



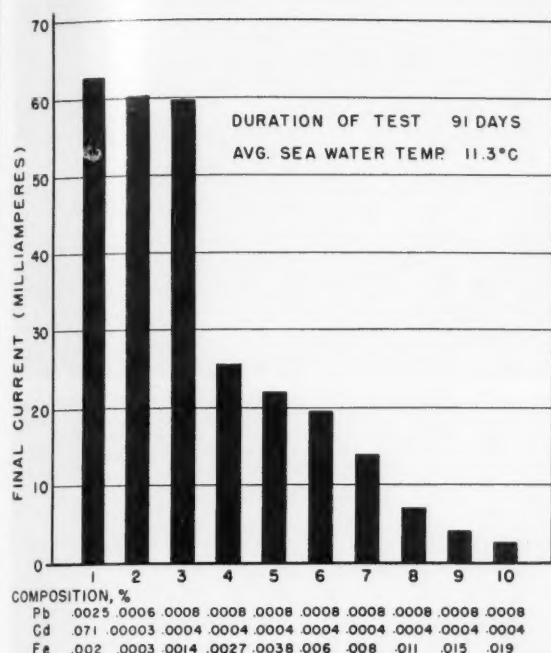


Figure 4—The final current output of zinc specimens working concurrently against a submerged steel tank.

value, while the iron content was varied from .0014 to .019 percent. This test was conducted with the same circuit arrangement used previously. While slight cathodic polarization occurred, it was felt that it did not interfere with the validity of the test nor the important conclusion derived therefrom (i.e., iron in zinc has a very deleterious effect).

The current output of these zincs working concurrently against the steel tank on the last day of the test period is shown in Figure 4. The other two zinc compositions "1" and "2" shown in this graph were included as a "control" zinc and a "base point" zinc, respectively. Zinc having a composition "1" had been used in previous tests, and its purpose was to serve as a means of comparing this test with those that had been conducted previously. The composition "2" zinc was the highest purity zinc available at the time, and it was included so that some idea could be gained as to the amount of current that might be expected from a zinc containing an infinitesimal amount of iron.

### Test Procedure

The foregoing tests led to the development of the test circuit shown in Figure 5. Each test circuit consisted of one zinc anode  $3\frac{7}{8}$ -inch x  $2\frac{3}{4}$ -inch x  $\frac{1}{2}$ -inch and a cathode of four steel plates, each measuring 3 feet x 3 feet. This provided 22.2 square inches of anode surface and 72 square feet of cathode surface with a steel to zinc area ratio of 470:1.

The zinc and steel were bonded together through a low resistance insulated wire and a 0.1 ohm current measuring precision resistor. Sufficient circuits were provided to enable tests to be run on 28 zincs at one time. The method of mounting the zinc on the plastic panel is shown in Figure 6.

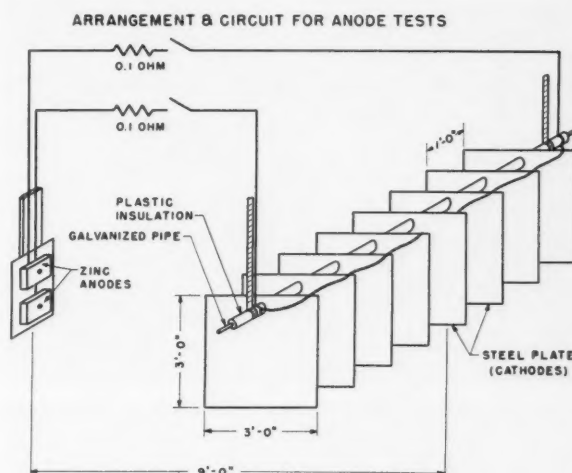


Figure 5—Arrangement and circuit for anode tests.

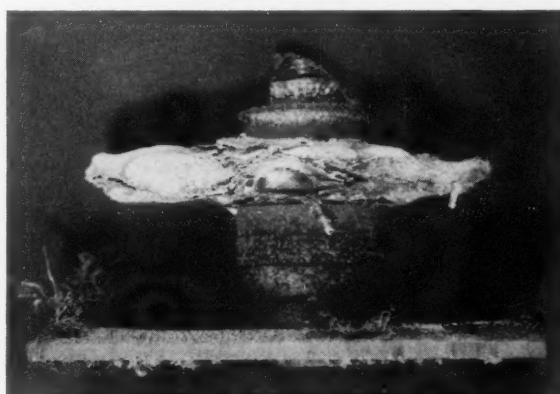


Figure 6—Cross-sectional view of zinc anode (top) in position on the plastic panel (bottom). Note spacing to eliminate shielding effect. Anode shown is corroded.

A daily potential drop reading across the resistor in each circuit was taken during the 31-day test period. These values were converted to current by Ohm's law in order to establish the relative current output characteristics of the various grades of zinc under study. All circuits were essentially the same and permitted direct comparisons between as many as 14 zinc compositions or grades in duplicate in any one test run. Differences in water temperature and fouling rates at various times limited direct comparisons of runs at the different times. This limitation, however, was largely eliminated by including a standard composition of zinc as a control or base for comparison in each test run.

Potential measurement showed that the cathode potentials changed from an open circuit potential of  $-640$  mv to  $-675$  mv<sup>(2)</sup> at the time the zincs were brought into their respective circuits. This slight polarization was not sufficient to warrant increasing the cathode area.

(2) Reference: Saturated calomel half cell.

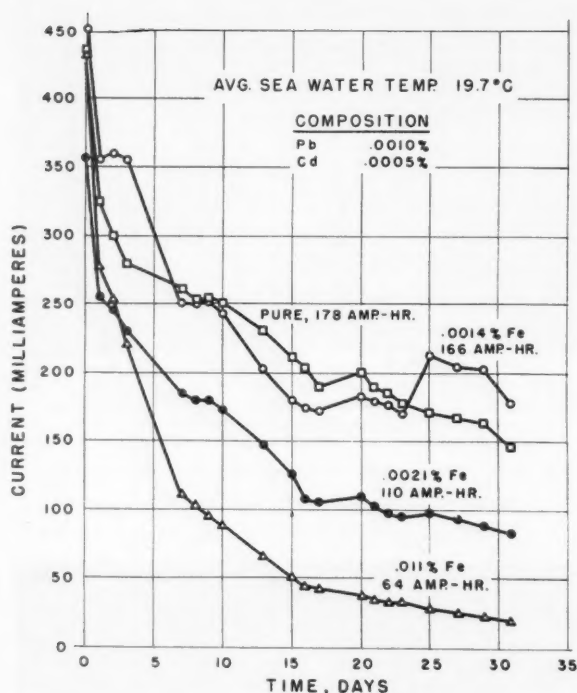


Figure 7—The effect of iron in galvanic zinc anodes in sea water.

Circuit resistance measurements were taken before and after test by using an AC bridge. In every instance the circuit resistance was greater at the end of the test than it was at the beginning. This increase in resistance has been labelled "film resistance" because the greatest part of it was caused by the resistance of the corrosion product film which was present on the surface of the zinc.

#### Discussion of Results

The current versus time characteristics of a number of the zinc galvanic anodes that were run in this test are shown in Figure 7. These values represent the average of duplicate specimens run at the same time. While the pronounced effect of iron when present in an amount greater than .0014 percent on the current output is quite evident, it is also apparent that the current output of spectrographically pure zinc, as well as those zincs with iron, decreases with time. Undoubtedly, a 35 mv change in the cathode potential was responsible for some decrease in the current output of the zinc. It is doubtful, however, that this was the only contributing factor.

The weight loss for each grade of zinc during the 31-day test period, along with the anode current output and film resistance on the last day of test versus the iron content of the zinc, is shown in Figure 8. Note that the film resistance is practically a mirror image of the current output. Impurities other than iron present in the zinc were in the special high grade zinc range.

The corrosion products present on the zinc were made up of two distinct layers. The outer layer contained mounds of corrosion products which were located directly over pitted areas on the surface of

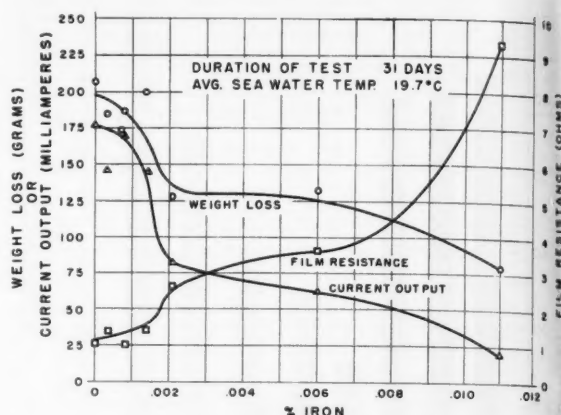


Figure 8—The effect of various iron contents in zinc used as a galvanic anode in sea water. All values are terminal values obtained on last day of test.

the zincs. The inner layer was more dense and contained an adherent black deposit that appeared in greater quantities on the zincs containing the greater amount of iron. The spectrographically pure zinc had a metallic silver colored deposit next to the zinc. All of the corrosion product films, with the exception of the films formed on the two grades of zinc containing the two largest amounts of iron, were soft, fragile and easily removed with a stiff bristle brush. The two exceptions required the use of an acetylene flame for removal.

Photographs of the anodes after cleaning are shown in Figure 9. Note that those anodes with a low iron content are characterized by a few, deep, large diameter corroded areas with a tendency toward uniform corrosion, while those containing a greater amount of iron have many shallow, small diameter pits scattered over their surface.

In this test, as well as in other tests undertaken as a part of this program, the galvanic efficiency of the zinc anodes, regardless of composition, was approximately 98 percent. Galvanic efficiency denotes the percent of weight loss that produces useful current and can be calculated by the following formula:

$$\text{Percent Galvanic Efficiency} = \frac{\text{Electrochemical equivalent} \times \text{current output (coulombs)}}{\text{weight loss (g)}} \times 100$$

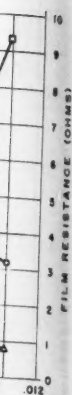
$$\text{Electrochemical Equivalent of Zinc} = 3.3875 \times 10^{-4} \text{ grams/coulomb.}$$

#### Conclusions

Numerous measurements have shown the open circuit potential of zinc in sea water to vary from -1055 to -1025 mv versus the saturated calomel half cell. Upon the passage of a few hours time, the potential settles down to a rather constant -1030 mv value.

The open circuit potential, as well as the initial current output of zinc anodes, appears to be independent of the composition of the zinc in the range of the compositions studied.

The major factor that controls the current output



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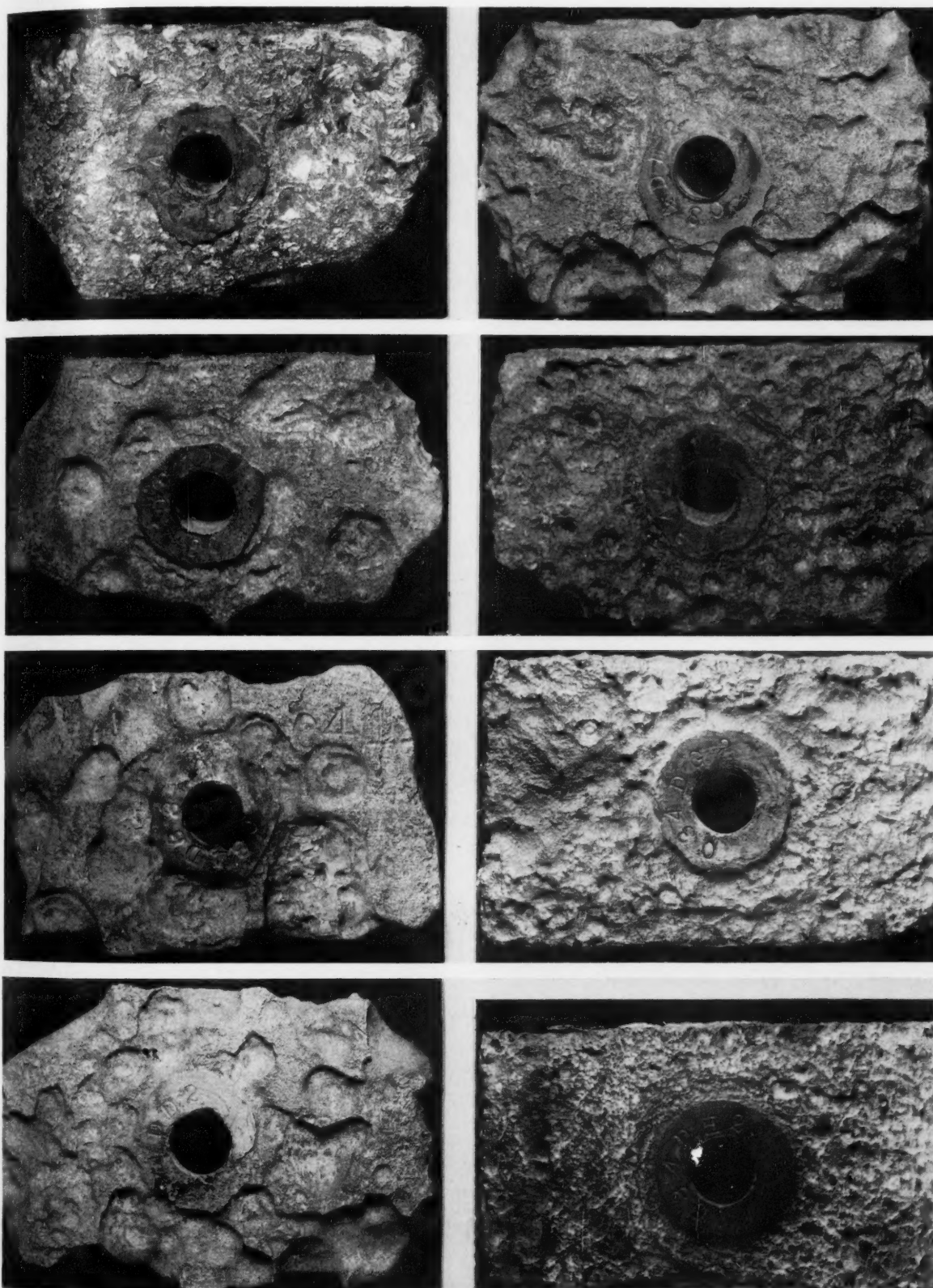


Figure 9—Zinc anodes after 31 day test. Corrosion products have been removed. All samples except the pure zinc contained .0010 percent lead and .0005 percent cadmium except as noted. Notations for samples are as follows: left, top to bottom—spectrographically pure; .0003 percent Fe; .0007 percent Fe; .0011 percent Pb; .0015 percent Cd; .0008 percent Fe; right, top to bottom—.0014 percent Fe; .0021 percent Fe; .006 percent Fe; .011 percent Fe.



characteristics of zinc in sea water is the character of the corrosion product film that forms on the surface of the corroding zinc. Both the electrical and mechanical properties of this corrosion product film are influenced by the presence of the minor constituents in the zinc.

All of the tests which have been undertaken during the course of this investigation have shown that iron is a highly undesirable contaminant in zinc. It is clear that its concentration should be limited to about .0015 percent or less. The need for maintaining the iron concentration at a value less than this has been accepted and is being specified by the U. S. Navy, Bureau of Ships.<sup>8</sup>

Corrosion product films on zincs containing iron have high electrical resistance and are tightly adherent. The mechanism by which iron is effective in reducing the current output of zinc is not clearly understood. Work done by May, Gordon and Schuldiner<sup>7</sup> showed the concentration of lead and cadmium in the corrosion product film to be 4.9 and 2.3 percent of the metal content, respectively, as compared to 0.4 and 0.3 in the original alloy that they were working. The iron concentration in the corrosion product film was not determined. The composition of zinc corrosion products has been discussed in detail by Anderson.<sup>9,10</sup>

The effect of other elements such as lead, cadmium, copper and aluminum is being investigated. Reports of this work will be published at some later date.

### Acknowledgments

The early stages of this investigation were made possible through the support and cooperation of W. C. Stewart and J. L. Basil of the United States Naval Engineering Experiment Station, Annapolis, Md., and John Godfrey of the Harrison Radiator Division of The General Motors Corp., Lockport, N. Y. It was largely through their early experience with zinc as galvanic protectors in Navy water coolers that this research was precipitated.

F. L. LaQue, T. P. May and H. T. Paterson have all made continuing contributions in this work.

E. A. Anderson of the New Jersey Zinc Co., Palmerston, Pa. has been particularly active in this investigation from its inception. His frequent consultations and contributions of virtually all of the test anode materials has been particularly helpful. He was largely responsible for the formation of The Zinc Anode Committee, of which he is the chairman, under the American Zinc Institute. The members of the committee are: E. A. Anderson (N. J. Zinc Co.), E. C. Reichard (American Smelting and Refining Co.), C. W. Ambler, Jr. (American Zinc, Lead and Smelting Co.) and C. C. Long (St. Joseph Lead Co.). The Institute through this committee has supported continuing research at Inco's Marine Laboratory at Harbor Island, N. C. on the effects of impurities and minor constituents in zinc. These studies include confirmatory researches on the effect of iron and additional studies on the effect of other elements such as cadmium, lead, copper and aluminum, the results of which will be published at some later date.

The very valuable help of all of the employees of

Inco's Kure Beach-Harbor Island Test Station, where all of these tests were conducted, also is acknowledged with appreciation.

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### DISCUSSION

Comments by E. C. Reichard and T. J. Lennox, Jr., American Smelting and Refining Co., South Plainfield, N. J.

The writers are to be complimented for the intensive studies completed on the performance of zinc as a galvanic anode. They have surmounted many of the major problems involved in tests of this type and the severe limitations imposed by facilities available. The following is work done as a contribution and addition to the work reported under the auspices of the American Zinc Institute Anode Committee and the International Nickel Company, Inc.

#### Check Tests:

In view of the intense effort, it was interesting to know if these data could be reproduced at another test location. In order to explore this question, the tidewater test facilities of the American Smelting and Refining Company were made available. Physical factors, duplicating the size and geometric arrangement of anodes, cathodes and circuitry of the Harbor Island test set-up were used.

The data obtained at the ASARCO test site, replicating Harbor Island procedures, are shown in Figure 1. These data confirm the broad conclusion of the basic paper, that iron in special high grade zinc

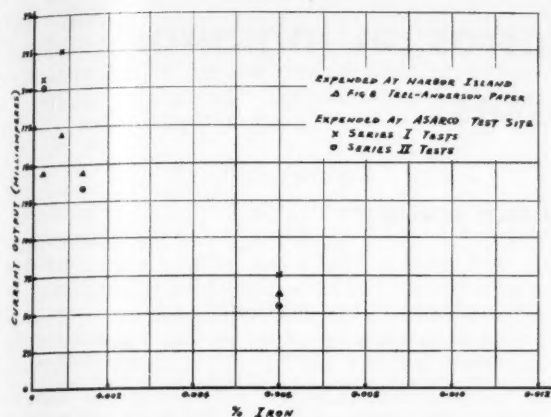


Figure 1—Final current output versus percent iron in special high grade zinc. Check tests were made on 22.2 square inch area test anode.

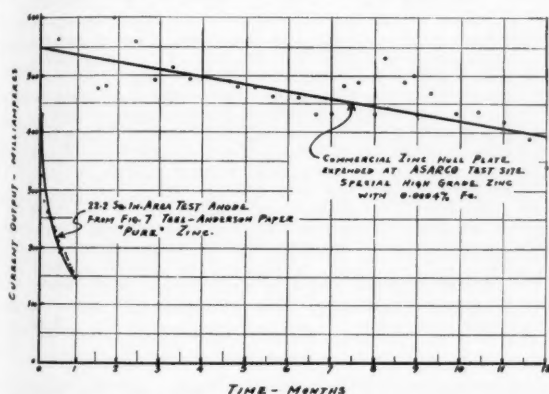


Figure 2—Current output versus time characteristics of commercial zinc hull plates and 22.2 square inch area test anode.

is detrimental to the performance of zinc as a galvanic anode.

#### Effect of Size:

Work reported in the Teel-Anderson paper and also presented so far in this discussion was confined to the 22.2 square inch area anode. The current output characteristics of this 37/8 inches x 23/8 inches x 1/2 inch anode as taken from Figure 7 of the Teel-Anderson paper are plotted in Figure 2. Also included are the characteristics of a commercial zinc hull plate (12 inches x 6 inches x 1 1/4 inches) as expended against an extensive steel bulkhead (15,000 square feet).

The current output of the 22.2 square inch area anode fell 67 percent from its initial level, during the 31 day test period. The current output obtained with the larger commercial sized anodes dropped less than 4 percent during the same time period. The 22.2 square inch area anode initially produced 430

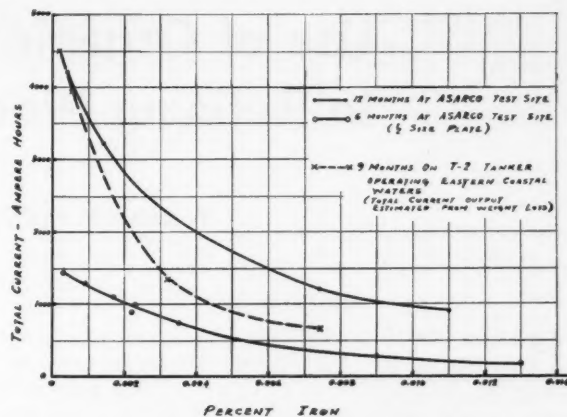


Figure 3—Total current output versus percent iron in special high grade zinc using commercial zinc hull plates.

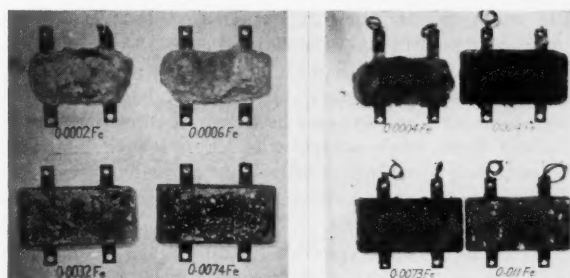


Figure 4—Effect of iron on performance of commercial zinc hull plates. Left photo: nine months—T-2 tanker operating in eastern coastal waters; Right photo: twelve months—ASARCO test site.

milliamperes against 550 milliamperes for the commercial zinc hull plate. The 22.2 square inch area anode was operating at a significantly higher anode current density. Thus current output characteristics and effects of composition on performance of larger zinc anodes become matters of interest.

Further investigation of size factors were conducted not only at the ASARCO test site but also on a commercial T-2 tanker hull operating in coastwise shipping. The results obtained from this latter series of tests have been plotted on Figure 3. These curves again confirm that iron is detrimental to the performance of special high grade zinc as a galvanic anode. The observations obtained from Harbor Island are confirmed except that no sharp break is obtained at the 0.0014 percent iron level. Photographs of the various anodes, as removed from test, are shown in Figure 4.

As the authors so aptly point out, this phase of work has been concerned only with the effect of iron. The effect of other elements on the performance of zinc and also in diminishing or accentuating the detrimental effects of iron remain to be presented.

Any discussions of this article not published above will appear in the December, 1956 issue.

# Use of Organic Corrosion Inhibitor In Refining Processes\*

By CHARLES FISKE\* and PAUL MERNITZ\*\*

## Introduction

PRIOR TO 1952, the crude oil processed at Leonard Refineries, Inc., Alma, Michigan, was entirely of Michigan origin. Later on this relatively sweet crude was largely superseded by high asphaltic Wyoming crudes, whose sulfur content posed much more acute corrosion problems.

Of primary concern to Leonard's engineers was the main crude distilling unit, a 90-foot vessel of bubble cap construction which contained 36 trays. The shell was of 3/8 inch mild carbon steel. Shell, trays, downcomers and all piping became much more subject to corrosive attack with the new crude. Debris from such attack was known to be capable of reducing distillation efficiency and throughput by fouling bubble cap slots and accumulating on the trays to serious depths.

Prior to 1952, conventional ammonia gas injection was the only means of corrosion control used on the distilling unit. Even with the sweet crudes processed, some relining and replacement of weakened internal structures had been necessary from time to time. There appeared to be no alternative to complete replacement of the unit with one constructed of more resistant materials, unless a much more efficient means of corrosion control could be found.

Processing of high sulfur crudes was started in January, 1952. At that time only a relatively small percentage of the crude charge consisted of the sour material, the rest being sweet Texas and Michigan stock. When the first crude unit inspection was made in September of 1952, the distilling unit was found to be in the worst condition of its service. Many of the bubble caps in the distillate and gas oil sections were completely plugged and large quantities of iron oxide and iron sulfide scale were taken from the tower. On some trays the loose scale reached a depth of several inches. Two trays in the distillate section were completely gone. Much more of the internal metal could be folded up like kraft paper and the bubble caps could be picked off the trays, their chimney T-bolts having been corroded through. Some data selected from the shut-down inspection report indicate the bad condition found at this time (Figure 1).

Records indicated that the ammonia addition had been sufficient to maintain the pH of the naphtha receiver water well above 7, averaging near 8. With pH control at this level shown inadequate, Leonard management was receptive to trying an organic cor-

## Abstract

An account is given of the use in a refinery of an organic corrosion inhibitor. Conventional ammonia injection to a pH of 8 or more in the receiver waters had provided inadequate protection to the usual sites of aggressive corrosion attack in the crude and synthetic crude fractionators, admiralty metal exchanger bundles and depropanizer overhead lines. A change from sweet to sour crude sources aggravated the situation.

Corrosion was strikingly reduced by proportioned injection of 20 ppm of inhibitor on crude input, as evidenced by coupon and inspection studies, and by daily receiver water iron content. The dosage later was reduced to 6-8 ppm based on overhead products plus reflux; the best point of injection was found to be the overhead reflux line. Normal flow of inhibitor apparently is downward. pH must still be maintained at 6.5 to 7.5 by ammonia injection. There have been no discoverable adverse effects on any refinery product at this dosage. While savings of ammonia have been about balanced by the cost of inhibitor, down-time for the pipestill due to restrictions from metallic sulfide accumulation has been cut to 25-35 percent of its former extent. Organic inhibitor has extended the life of the tower several years beyond that expected with ammonia protection alone. 5.8.2

rosion inhibitor,<sup>1</sup> specifically proposed for prevention of corrosion and fouling in refinery equipment.

At first, the primary interest was in protecting the bottom section of the main crude unit. On November 29, 1952, injection of the corrosion inhibitor was begun at a point on the same level as the crude inlet to the tower and 90 degrees around from the crude inlet nozzle. The temperature at this zone was about 560 F.

It was hoped the question of whether or not the inhibitor was capable of protecting this very critical part of the tower could be quickly answered. Deciding upon the proper dosage was rather difficult in view of the newness of the situation. It was decided that 20 ppm of inhibitor should be tried on the crude input as a maximum figure. It was expected that the dosage might be reduced as much as possible as the picture became clearer. With charging rate at the time of about 6,900 barrels per day of crude, 40 pounds per day of inhibitor were required.

This organic inhibitor is a proprietary compound which is soluble in aromatics and dispersible in water. The inhibitor also is dispersible in aliphatics when continuous mild agitation is provided. Because of a convenient source of kerosene, a 15 percent dispersion of inhibitor in this product was made up in a blend tank on a daily basis and kept in suspension by means of a small continuous air spray.

Leonard's experience has been that scheduling a

\* Submitted for publication February 21, 1955. A paper presented at the Eleventh Annual Conference, National Association of Corrosion Engineers, Chicago, Illinois, March 7-11, 1955.

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tank blending operation each day fits much better into the duties of the workmen than scheduling a large amount. The operators seem much less likely to overlook a daily task than one which comes up at odd intervals of several days.

### Test Procedures

In order to test the effectiveness of the inhibitor two procedures were established. First, it was arranged to make a daily test of the iron content of the naphtha receiver waters so as to have a constant check during onstream conditions. Occasional spot checks on this water during the ammonia injection period had revealed very erratic results, with iron assaying up to 300 ppm on some occasions and very frequently in the 100-150 ppm range even with average pH no lower than 8. A test kit for colorimetric determination of iron was used.

Second, and in order to supplement this test on a somewhat more accurate basis, corrosion coupons were placed in the tower on the tray near the distillate draw-off level and in the top of the tower. It was considered that these data along with the metal inspection report on shut-down would give a satisfactory indication of the effectiveness of the inhibitor.

It was hoped that the amount of ammonia used for the prevention of corrosion could be materially reduced by the addition of the organic corrosion inhibitor. After receiver-water iron content indicated that satisfactory protection was being obtained, the ammonia addition rate was gradually decreased, thereby reducing the pH of the receiver water. Figure 2 shows for each of the two sets of conditions described, the pH range under which negligible iron was detected in the receiver waters (solid bars) contrasted with the pH range at which an unsatisfactory level of iron was found (outlined bars).

The somewhat unusual means of presenting these data was dictated by the experience that the iron content found on daily control test generally was either negligible or quite high (greater than the 30 ppm maximum established for the test) and almost never in the 1-30 ppm range. This figure compares two periods, of seven and six months, respectively. For the former period, inhibitor was added totalling 20 ppm and pH was controlled by injection. It will be seen that substantially good protection (i.e., low iron content in the naphtha receiver water) was had above about 6.5 pH.

In the latter run, no inhibitor was added. A pH of nearly 8 had to be maintained with ammonia alone to give reasonably good protection to the metal. As shown, lower pH values were found to give satisfactory protection when inhibitor was used. But because it was difficult to maintain precise pH control with the setup available, it was decided the control limits would be set from 6.5 to 7.5 for ammonia addition.

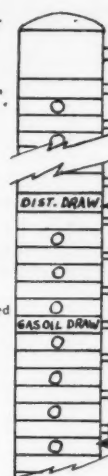
The first opportunity to examine corrosion coupons came during a short shut-down in January, 1953. While the metal loss during the two month exposure was not great, (see second entry on Table 1) a relatively small proportion of very corrosive crude had

### SUMMER 1952

#### NH<sub>3</sub> ONLY

#### TRAY LEVEL COMMENT

- 1-3  
(1-2) "Scale piled up"  
(2) "Center of tray gone"  
"Baffles gone or paper-thin"
- 15-30  
Bubble Caps generally clogged and dirty  
Eleven new weirs needed in mid tower  
(23-28) Six new trays needed  
(24) "Many loose caps"  
"Tray very dirty"  
(27) "Tray collapsed"



### SUMMER 1953

#### NH<sub>3</sub> + INHIBITOR

#### TRAY LEVEL COMMENT

- 1-3  
"1/8 inch scale covering internals"  
"One segment of first tray corroded thin"
- 15-30  
"INJECTOR, Naphtha - JAW'S" (16) Baffle thin. Weir OK  
(20) Several chimney rings missing  
(Mid tower) Evidence that previously clogged caps are opening up  
No loose caps found  
"INJECTOR, Naphtha - JAW'S" (30) "Downcomer thin"

Figure 1—Abstract of metal inspection reports for crude unit.

TABLE 1—Crude Unit Protection Using Organic Inhibitor

| Inhibitor   | Conditions                        | Penetration of Coupons in MPY <sup>1</sup> |                 |          |      |            |      |
|---|-----------------------------------|--|-----------------|----------|------|------------|------|
|   |                                   | Top  |                 | Top Tray |      | Dist. Draw |      |
|   |                                   | 405SS                                      | MS <sup>2</sup> | 405SS    | MS   | 405SS      | MS   |
| None  | Semi-sour crude, two month period | 1.52                                       |                 |          |      |            |      |
| Twenty ppm inhibitor, applied near crude inlet                          | Semi-sour two month period        | 0.42                                       | 0.42            |          |      | 0.40       | 1.19 |
| Twenty ppm inhibitor, applied near distillate draw.                     | Sour, five month period           | 3.25                                       | 38.91           |          |      | Nil        | Nil  |
| Twenty ppm inhibitor, applied near distillate draw and overhead reflux. | Sour, seven month period          | Nil  | Nil             |          |      | Nil        | Nil  |
| No inhibitor—High pH control  | Sour, six month period.           | 0.56                                       | 1.73            | 0.30     | 4.05 | 0.005      | 2.29 |
| Six ppm inhibitor, applied to overhead reflux.                          | Sour, six month period            | 0.11                                       | 0.53            |          |      | Nil        | 1.57 |

<sup>1</sup> Mills per year.

<sup>2</sup> Mild carbon steel, ASTM A-285 Grade C, flange quality

been processed. This, coupled with the fact that receiver water samples showed erratic iron content, led to the idea that injection higher in the tower might stabilize the protection. Provision was made therefore to inject the inhibitor at the vapor space of the distillate draw tray.

When the crude unit was next shut down for inspection in August of 1953, visual inspection showed the tower to be in very good condition. A film of corrosion inhibitor was found on the metal all through the lower section of the tower. Almost no scale or dirt was found on the trays and it appeared that the slots in the bubble-caps were slightly cleaner than previously. The right side of Figure 1 shows data taken from the metal inspection report at the time of this cleanout. The contrast between the con-

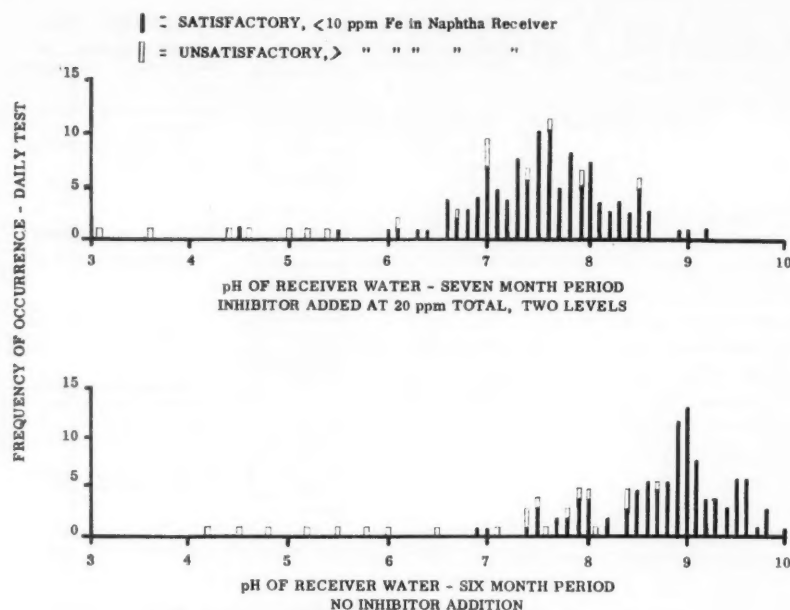


Figure 2—Crude unit protection with an organic inhibitor.

dition at the times of these two inspections is fairly striking. Old refinery hands who had come over the years to expect "another patch job" and certainly the removal of several loads of assorted scale and debris, were most impressed with the obvious improvement.

During the five month period following the January inspection a large proportion of sour crude had been run. In spite of having anticipated a need for raising the injection level in January, coupons from the top of the tower (third entry, Table 1) indicated that the tower still did not have adequate corrosion protection for the overhead vapor space. The corrosion coupons at the distillate draw level had lost no metal, and appeared to have an oily protective film. The tower generally had been protected in the same way at lower levels. The very high rate of metal loss on the top coupons seemed to confirm fears regarding the very corrosive nature of the new crudes.

Note the great increase of metal loss from the top coupons in this period of change from a low to a high proportion of sour crude (see second and third entries, Table 1). Because of this development it was decided to add a second stream of inhibitor into the naphtha reflux to the top of the tower. All of this experience tended to show that the general course of inhibitor was downward through the tower.

The metal inspectors also found a rubberlike mass about the size of a football in the tower immediately in front of the inhibitor inlet at the vapor space of Tray 14. The inhibitor manufacturer speculated that this formation was caused because the kerosene which was used as a diluent flashed off immediately, leaving the concentrated inhibitor at a fairly high temperature in the vapor space of this tray. He recommended that the inhibitor be added into the liquid section of the tray instead of the vapor section. Provisions were made to add the inhibitor below the

liquid level on this tray. Subsequent operation has not indicated any further concentration of undispersed inhibitor at this level.

### Increased Dosage

As time went on, the dosage to the top of the tower was gradually increased. Because the material was cheap in comparison to the benefits received, relatively little attention was given to using the optimum concentration. It was found, however, that an emulsion was being formed in the caustic scrubber which carried over into the copper treater and contaminated the copper reagent. In the process of systematically eliminating possible causes, this emulsion problem was stopped by taking the corrosion inhibitor out of the tower. As a result the iron again increased in the receiver water. During this five month period, it

was necessary to step up ammonia injection to give at least a pH of 8 in the receiver water, to keep the corrosion rates even partially under control. Apparently excessive dosage had caused the emulsion. This seemed especially true in view of the fact that there was rather restricted residence time in the settling drums after caustic scrub. A closer look at dosage was indicated inasmuch as it affected adequate protection on the one hand, and emulsion problems on the other. A separation time curve for a range of dosages was plotted using plant scrub caustic of 17 degrees Bé in equal parts with the inhibited gasoline. It was found that the increase in separation time is definite, but gradual enough so that a relatively broad range of dosage should be available while reasonable corrosion protection was being maintained. Inquiry about the experience of other refineries established that the emulsion problem was not a determining factor.

The inhibitor addition was begun again into the tower. This time much closer attention was paid to the minimum dosage. Inhibitor was fed into the reflux line, using only 6 ppm based on the overhead product plus the reflux back to the tower. Visual inspection plus corrosion coupons (sixth entry, Table 1) indicated that the company was getting nearly as good protection with this dosage as they had obtained with the higher dosage. No further trouble was encountered with gasoline caustic emulsions in the treating system.

The last line of Table 1 shows that .5 mpy pene-

TABLE 2—Reduction of Downtime Due to Tower Plugging Only

| Year | Shutdowns | Total Hours |
|------|-----------|-------------|
| 1950 | 3         | 178         |
| 1951 | 4         | 195         |
| 1952 | 3         | 92          |
| 1953 | 4         | 77          |
| 1954 | 3         | 51          |

July, 1956

tration of mild steel occurred at the top and about 1.5 mpy at the distillate draw level. It is felt that even this may represent upset conditions where pH control was erratic, inasmuch as visual examination of internal surfaces still shows very generally a protective organic film. Because this film is constantly being eroded off and renewed, delay in the renewal process caused by transient pH changes probably led to the reported corrosion on this set of coupons.

After the engineers concerned were satisfied that they were obtaining protection with the use of organic corrosion inhibitor, they injected additional streams of corrosion inhibitor into other vessels whenever inspection indicated a corrosive problem. For example evidence was found of pitting on the hydrocarbon side of the admiralty tubes in the overhead exchangers for the cat-cracked gasoline. An inhibitor dosage of about 20 ppm based on overhead and reflux in the overhead vapor line of the synthetic crude tower led to the reduction of the copper picked up by the cat-cracked gasoline from 0.1 mg per liter to the lower limit of test, about 0.01 mg per liter. A visual inspection of these exchangers at the time of the last cleanout also indicated satisfactory performance.

#### Protection of Internal Walls

Another refinery corrosion problem is the protecting of the internal walls at the gasoline-water interface of the gas and water separator. Corrosive attack in that area has been found to be extremely aggressive. The separator contains warm cracked gasoline; in addition the steam condensate contains water-soluble sulfides and phenols and overhead sour condensable gases produced in the cat-cracking operation. No paint or other reasonably-priced protective system used in the past three years was found to withstand completely this rough service. There has been no chance to examine the inside of this vessel since the inhibitor has been used in the stream, but it might be expected that some protection is being obtained. In past years, the appearance of ferrous sulfide in the effluent waste water from this vessel has been a reliable indication of aggressive attack. There has been no evidence of this product during the period of inhibitor addition to the gasoline, which gives some ground for optimism.

Another application which was indicated for the corrosion inhibitor is the reflux line of the depropanizer. When pitting was noted on the hydrocarbon side of the overhead exchanger on the depropanizer, an initial dosage of about 10 ppm, based on depropanizer overhead product plus reflux, was used.

There has been no concern with the fate of the inhibitor that has been used, except as it could adversely affect any of the hydrocarbon products with which it comes in contact. Earlier it was shown that certain emulsion problems during caustic-scrubbing operations seemed to be traceable to excessive dosage of inhibitor in the crude unit. At about the same time, a similar problem arose in scrubbing the cat-cracked gasoline stream, and the solution to the problem was the same. That is, from an initial dosage of 20 ppm, inhibitor addition was reduced to

about 8 ppm based on total overhead and reflux rate in the synthetic crude tower.

No adverse effect on the products has been found at all—rather the opposite, in that cleaner equipment has made closer control of distillation possible. Gum formation, induction period and other tests having to do with gasoline stability have come in for particular scrutiny, but no trouble has been found traceable to inhibitor use.

It is important, of course, to arrive at some estimate of the savings involved in this system of corrosion inhibitor as compared with the prior system, when ammonia alone was used. Some saving of ammonia is effected, but the saving is just about balanced by the cost of the inhibitor used. More important was that it was soon obvious to the operators that a cleaner tower was capable of much better fractionation, and that down-time for cleaning the unit was definitely being reduced.

As is usual in refinery practice, the authors' company has one major turnaround yearly, with as few other shutdowns as necessary to effect minor repairs or correct upsets. Table 2 illustrates the trend from 1950 through 1954, in which has been tabulated hours of downtime on the crude unit due to equipment failure on the product side. Annual turnaround figures are not included, inasmuch as crude unit inspection and repair at such times is not the determining factor.

Every refinery will of course have its own estimate of the cost of an hour of offstream time.

In conclusion, it can be said that Leonard has credited the organic corrosion inhibitor with prolonging the life of the crude unit tower to the extent that it was able to delay any revamp or replacement of this tower until such time as increased capacity requirements warrant construction of new equipment. It has been found that the dispersant action of the inhibitor effectively keeps the equipment clean which in turn results in (1) better fractionation, (2) better heat exchange in coolers, (3) far less severe plugging, and (4) less downtime. Maintenance costs are reduced accordingly. The inhibitor, because of its coating effect on the metal, is more capable of maintaining protection during minor upsets than is the more volatile and fugitive ammonia. At reasonable dosage it has not been found to affect any refinery product adversely.

#### DISCUSSIONS

**Question by Andrew Dravnieks, Standard Oil Co. (Ind.), Whiting, Indiana:**

What were the corrosive agents in the given case? Generally, they may be sulfur compounds, chloride or organic acids.

**Reply by Charles Fiske:**

The most severe corrosion occurred through the center of the tower in the area of our distillate draw section. Our findings show that the corrosion was due primarily to sulfur compounds, rather than to chlorides or organic acids. Throughout the entire



period in question uniform desalting has been obtained; the excessive corrosive rates started after we started processing the higher sulfur crude. The chloride or salt content did not change from the time during which we were processing sweet crude and when we started charging sour crude to the unit. It is our observation, therefore, that the increased corrosion rates were due primarily to the increased sulfur content of the crude charge.

**Questions by Kenneth R. Barker, Ashland Oil and Refining Co., Ashland, Kentucky:**

1. Did you attempt to evaluate the reduction in fouling which resulted in the exchangers in the bottom draw circuit?
2. What was the maximum temperature at which the inhibitor was effective?

**Replies by Charles Fiske:**

1. Our most recent inspections have revealed no effects in the bottom draw circuit which could be credited to the inhibitor injection.
2. Definite improvement in corrosion protection was found from the gas oil section upward. Maximum temperature would be about 525 F.

**Question by W. M. Kyger, Arkansas Fuel Oil Corp., Shreveport, Louisiana:**

Have you eliminated the formation of emulsion from the use of the organic inhibitor?

**Reply by Charles Fiske:**

The emulsion resulted from an overdose of inhibitor. The initial addition was 20 ppm based on crude input. When the addition points were moved to the top of the tower, carryover to the caustic scrub first appeared. This was aggravated by raising the dosage several fold. The caustic scrub, a closed system, probably concentrated the additive to unknown but high levels. As described in the paper emulsion is not now a problem.

**Question by James R. Moore, St. Louis, Mo.:**

Do the inhibitors give good overall protection (e. g., is the entire bundle of a condenser protected) or do you have to have several points of injection?

**Reply by Charles Fiske:**

Injection in the top of the towers at recommended dosages has shown enough carryover to protect the entire overhead condenser bundles.

*Any discussions of this article not published above will appear in the December, 1956 issue.*

# NACE TECHNICAL COMMITTEE REPORTS

Publication 56-13

## Fourth Interim Report

# Cathodic Protection of Lead Sheathed Cables In the Utilities Industry

Technical Unit Committee T-4B on Corrosion of Cable Sheaths<sup>(1)</sup>  
(Prepared by Task Group T-4B-2 on Cathodic Protection of Cable Sheaths<sup>(2)</sup>)

### INDEX TO SUMMARY QUESTIONNAIRE NO. 1

Replies Begin  
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#### A. Protective Criteria

1. Does your company have a set of rules relative to maximum and minimum allowable cable to earth potentials for various types of cables, i.e., plain lead, copper jacketed, tape and wire armored, thermoplastic, jute covered, polyethylene, etc. If so, will your company submit a set of these limits for study by this committee? Otherwise, will you outline your maximum and minimum cable to earth potentials for the various types of cables you have in your plant.
2. Does your company use special methods to avoid cathodic corrosion? If so, will your company submit your method for study by this committee? Otherwise, will you outline the methods you use to avoid cathodic corrosion on your cable plant.

#### B. Rectifier Ground Bed Design and Location

1. Does your company have a set of rules relative to the design and placement of the rectifier ground bed for the protection of lead sheath cables?
  - a. For a point type ground bed.
  - b. For a distributed type ground bed.If so, will your company submit these rules for study by this committee? Otherwise, will you outline the rules you use relative to the design and placement of rectifier grounds?
2. Does your company have a set of rules relative to interference measurements with other substructures before installing rectifier ground beds? If so, may they be studied by this committee? Otherwise, will you outline the methods you use to minimize interference with other substructures when placing rectifier ground beds?

#### C. Installation of Galvanic Anodes for Cathodic Protection of Cable Sheaths

1. Will you outline here any comments you may have regarding the use of anodes for the cathodic protection of cable sheaths?
  - a. Aluminum
  - b. Magnesium
  - c. Zinc

#### D. Rectifier Characteristics Relative to Lead Sheath Cable Protection

1. Briefly outline your experiences with various types of rectifiers.
  - a. Selenium, copper oxide, tungar, others
  - b. Efficiency
  - c. Interference filters
  - d. Surge and lightning protection

#### E. Insulating Joints as Used to Mitigate Adverse Electrolysis Effects

- a. Aerial, underground, buried cables

#### F. Protective Coatings for Lead Cable Sheaths to Mitigate Sheath Corrosion

1. What use does your company make of protective sheath coverings?
  - a. On original installation
  - b. On cable repairs, either caused by electrolysis or mechanical damage.

<sup>(1)</sup> Irwin C. Dietze, Dept. of Water and Power, Los Angeles, Cal., chairman.

<sup>(2)</sup> Russell M. Lawall, American Telephone and Telegraph Co., Cleveland, Ohio, chairman; J. J. Pokorny, Cleveland Electric Illuminating Co., Cleveland, Ohio, vice-chairman.

### Abstract

Replies to two questionnaires concerning lead and copper-jacketed cables are summarized. Seventeen power companies, 10 communication companies and one electrolysis committee sent replies.

Cathodic protection criteria: Negative potentials used ranged from .05 to 0.5 volt negative, with some preference for 0.2 to 0.3 volt negative. Currents used to protect steel tape or wire armored cable were in the vicinity of 0.85 volt negative to a copper-copper sulfate electrode near the cable. On copper-jacketed cable a potential of 0.1 to 0.25 volt negative is used.

Ground Bed Design and Location: Scrap steel, iron and cable are used either in point or distributed beds. Some inert anodes are used in point beds and a few installations of magnesium galvanic anodes are reported.

Power Source: Selenium rectifiers are preferred but other kinds, including vacuum tube types are reported on.

Protection Coordination: Most users of rectifiers report some kind of protection coordination among plant operators.

Interference Filters: Used to prevent noise on telephone circuits.

Surge and Lightning Protection: Some operators provide means of grounding surges or lightning charges.

Insulating Joints: Some use is reported, especially on cables entering office buildings, between aerial and underground cables and in stray current areas. Numerous uses for insulating joints on power cables are reported.

Protective Coatings: Some use is reported and no user reports damage from cathodic protection currents. 7.7

### INDEX TO SUMMARY QUESTIONNAIRE NO. 2

Replies Begin  
On Page

#### A. Protective Criteria

1. What criteria does your company employ to determine adequate cathodic protection for:
  - a. Plain lead sheath?
  - b. Copper jacketed?
  - c. Tape and wire armored?
  - d. Thermoplastic?
  - e. Jute covered?
  - f. Polyethylene jacketed?
2. What limits do you strive to obtain?

#### B. Rectifier Ground Bed Design & Location

Describe your method of ground bed design and installation.

#### C. Insulating Joints

Are insulating joints used in any manner in connection with cathodic protection (either rectifier or galvanic anode) for control of the protective current?

Replies Begin  
on Page  
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#### D. Protective Coatings

1. Are protective coatings used in any manner to reduce the size of the cathodic protection installation (rectifier or galvanic anode)?
2. Have you experienced any detrimental effects of cathodic protection currents on your protective coatings?

### CURRENT PRACTICES\*

#### Discussion of Replies to Questionnaires No. 1 and 2

##### Introduction

Most underground systems consist of lead sheath cable installed in non-metallic ducts such as tile, fibre, concrete, wood, etc., laid in soil. Generally only the bottom of the cable is in contact with the duct. To some extent the duct wall restricts the flow of electric current between the external soil and the cable, and in so doing acts as a semi-protective coating for the cable. Thus, a cathodically protected cable system installed in non-metallic ducts and insulated from other systems should have little influence, that is, little tendency to produce stray currents.

On the other hand, lead cable installed in metallic ducts in the earth can be considered to have a relatively high influence so extra care should be taken to provide electrical drainage or cathodic protection to such systems or portions of systems to prevent jeopardizing other cables or pipes in close proximity.

Except where otherwise indicated, the duct-lay cables covered in this report are considered to be lead sheathed cables installed in non-metallic ducts.

The analysis which follows is based on current practices of 17 power companies, 10 communication companies and one electrolysis committee. All 30 of the companies represented in the survey replied to questions pertaining to lead sheathed cables in underground ducts, 7 replied to questions involving steel tape or wire armored cable and only 3 to questions involving copper-jacketed cables.

##### Protective Criteria

**Lead-Sheath Cables in Ducts:** Most companies consider a satisfactory criterion of adequate cathodic protection to be a negative sheath potential referred to a lead or lead-chloride electrode in contact with the earth, the bottom of the manhole or placed in a vacant duct. The magnitude of the negative potentials mentioned usually ranged from .05 to 0.5 volt, with preference shown for 0.2 to 0.3 volt in several replies. Two companies look for a change of sheath potential in the cathodic direction of 0.3 volt and one company, using a copper sulfate electrode as a reference, considers that a lead sheath potential of 0.75 volt with respect to a copper sulfate electrode indicates a cathodic condition.

**Steel Tape or Wire-Armored Cables:** This type of cable is laid directly in the earth and the usual criterion of adequate protection is a 0.85 volt negative potential of the armor referred to a copper sulfate electrode on the earth's surface above the cable.

**Copper-Jacketed Cable:** Here again, the copper sulfate electrode is used as the reference electrode and a jacket potential of 0.1 to 0.25 volt negative referred to the electrode is regarded as a criterion of adequate cathodic protection.

##### Rectifier Ground Bed Design and Location

Major portions of power and communicating company underground plants are located in urban areas. As a result of their variable locations, the cables do not have substantial uniformity of sheath cross-section, nor are they in uniform proximity to other structures for any considerable distance. It is these variances in plant density and location, coupled also with economics and the advancement in corrosion protection practices that has led to a variety of cathodic protection systems.

##### Power Source

The specific current requirements for adequate protection of a cable will dictate the capacity of the DC power and ground bed. Source of the power may be from rectified AC or generated DC. Rectifiers provide an efficient, low cost and low maintenance source of DC. A few vacuum tube rectifiers are in use, but are only efficient near full load outputs. Current

output of tube rectifiers is low compared to selenium or copper oxide rectifiers of comparable size. Recently a selenium rectifier unit was combined with a saturable reactor to make a magnetic amplifier which acts as a valve to automatically control the protective current within limits dictated by a control voltage. (Usually some other substructure.)

##### Types of Anodes Used

It has been general practice in the past to use such items as scrap pipe, boiler tubing, railroad or trolley rails, steel piling, steel beams and junk cable as sacrificial anodes for cathodic protection systems. They have been used mainly because of the low initial cost and are economically justified in some cases because they were already in the earth. Due to the solubility of iron and lead scrap these anode installations are able to provide only roughly one percent of the ampere hours per pound obtainable from a carbon or graphite rod ground bed. Graphite anodes are preferable to carbon due to their greater resistance to electro-chemical oxidation. Graphite anodes, which are impregnated with sodium to eliminate porosity, are used in extremely acid or salty environments.

##### Type and Location of Ground Bed

The proper selection of a location and the type of ground bed in a cathodic protection system is based on factors that affect the total cost of the installation and the possible interference to other structures. Two general designs of ground beds are in use: The point type and the distributed ground bed.

The point type ground bed consists of a ground bed made up of one or several anodes grouped in a location. Point type beds are low in cost and require minimum right of way.

Distributed ground bed installations consist of anodes spaced over a distance along the cable route. This method of protection provides a means of adjustable current distribution over a considerable length of cable. Small quantities of current can be controlled with resistors to give the needed amount of protection at any point. Anode installation is relatively high, but influence on other structures can be reduced to a minimum.

Where the choice of a ground bed location is not restricted, the four electrode-megger test method can be used to prospect for the areas of lowest soil resistivity. A low resistance ground bed reduces the voltage required to obtain the protective current and correspondingly reduces the cost of the rectifier installation. With a consistent soil resistivity, a straight line anode bed is the most efficient design. It has been proved economical in some cases to place anodes at various depths up to 50 feet in order to obtain low resistance ground beds.

In urban areas ground bed locations are restricted generally due to the close proximity of other underground structures and the presence of railroads, buildings, etc. This leads the engineer to a design considered on available space rather than low earth resistivity. Scrap cable or sectionized graphite anodes are pulled in a vacant duct and used as a ground bed. In some cases, graphite anodes or scrap steel rails are placed between or adjacent to the duct banks. Burial of anodes in the manhole floor has also been practiced.

##### Method of Installation

Scrap material anode installations are made in a variety of methods depending on the material used and the location. When junk cable, abandoned trolley rails and pipe are used, not much can be done to improve ground bed resistance. Where scrap steel is purposely buried for use as an anode bed, resistance can be lowered by providing prepared backfill. Various mixtures of salt, earth and coke breeze have been used to accomplish a low resistance to earth. The backfill provides an increased surface active as an anode for current discharge and so lengthens the anode life by transferring attack from the anode to the backfill. With greater anode surface and reduced resistance, larger currents can be carried by the anode.

In the installation of carbon or graphite anodes, three different types of backfill are in use: Calcined coke, metallurgical coke and alkaliized graphite. The graphite backfill is preferred when a long anode life is important. Sufficient backfill usually is placed to extend above and below the anode about one foot with minimum surrounding backfill of one anode diameter. The recommended current density on graphite anodes, operating in a carbonaceous backfill of the approved type, is one ampere per square foot of anode in order to give a useful life of 10 years. Without a backfill, only one-fourth ampere can be realized for the same anode life.

Prepared by:

\* F. E. Kulman, Consolidated Edison of New York, Inc., New York, N. Y.; R. M. Lawall, American Telephone & Telegraph Co., Cleveland, Ohio; J. J. Pokorny, Cleveland Electric Illuminating Co., Cleveland, Ohio; L. Schwalm, The Ohio Bell Telephone Co., Cleveland, Ohio.



### Protection Coordination

Most users of rectifiers are cooperative in interference problems. They notify other underground plant users in the vicinity of their intention to place protection. Plans of the rectifier installation are submitted to interested parties and preliminary interference tests are made using a temporary ground bed. Additional cooperative influence tests usually are made after the permanent installation is in operation. Other companies belong to electrolysis committees whose function it is to supervise and test the interference of the proposed installation. The ultimate plan is worked out to the mutual satisfaction of all concerned through relocation of the ground bed or an interconnection of plants with resistive bonds if necessary to mitigate the interference problem.

The degree of interference to other structures from a cathodically protected cable depends on the influence of the protected cable, the susceptibility of the other structures and the coupling between the cable and other structures. Proper design of the protective system can eliminate the majority of these factors that affect the interference caused to other structures.

The engineer's efforts to prevent interference in the design of a protective system often are upset by limited choice of an available ground bed location, the inconvenience of construction and the lack of available power for the installation.

The 1951 Report of the Correlating Committee on Cathodic Protection<sup>1</sup> provides a discussion of fundamental concepts underlying applications of cathodic protection.

### Galvanic Anodes for the Protection of Lead Cable Sheaths

It is indicated that magnesium anodes are used in underground conduit as follows: Packaged anodes in earth below manhole floor; in underground dips; packaged anodes buried outside the manhole. Use of magnesium is limited when the number of cables exceeds three. Magnesium can be considered for use with Neoprene jacketed cables.

Bare anodes may be placed in manholes in manhole floors. Magnesium anodes cannot be used when cable sheaths are in electrical contact with water system, or in stray current areas. Magnesium anodes are used on buried cable with good results. Magnesium ribbon in ducts is generally unsatisfactory. If used, the ribbon must be moved periodically. Usually all protection is lost after approximately 20 percent of magnesium ribbon anode is consumed.

Aluminum anodes do not have as great driving potential as magnesium.

Zinc anodes become polarized except in salt water areas.

Other uses for magnesium: To protect steel ground rods; to protect submerged underground transformers and other manhole equipment; to protect steel pipes of pipe type cable.

### Rectifier Characteristics Relative to Lead Sheath Cable Protection

#### Type of Rectifier

**Selenium**—One company indicated that of 48 rectifier installations, the selenium type gave the best efficiencies. Selenium rectifiers are being used for most new installations. Less maintenance is required in their use.

**Tungar**—Tungar bulb life was found to be about 10,000 hours. Tungar rectifiers are no longer being installed due to maintenance considerations. If available in supplies they are still used.

**Copper Oxide**—Copper oxide rectifiers are being used satisfactorily. Some copper oxide rectifiers are reported to have as low an efficiency as 15 percent. Some rectifiers have had a tendency for edge corrosion of the discs. Average efficiency of copper oxide rectifiers appears to compare favorably with selenium.

**General**—Sometimes rectifiers have been sealed in lead and installed in manholes.

#### Characteristics and Efficiency

A paper presented by T. J. Maitland at the Annual NACE Conference in Galveston, Texas, in 1952 furnished information on the efficiencies of 52 rectifier installations used for the protection of communication cables. The results of these tests are shown in Figures 1, 2 and 3 for electronic, selenium and copper oxide types respectively. Table 1 gives a summary of the percent capacity and percent efficiency found on actual test of these 52 installations.

It will be noted that a majority of both the electronic and selenium type rectifier tested were operating at 50 percent or less of their capacity. A study of operating data on a total of 121 rectifier installations also gave similar information indicating that a majority of such rectifiers were operating

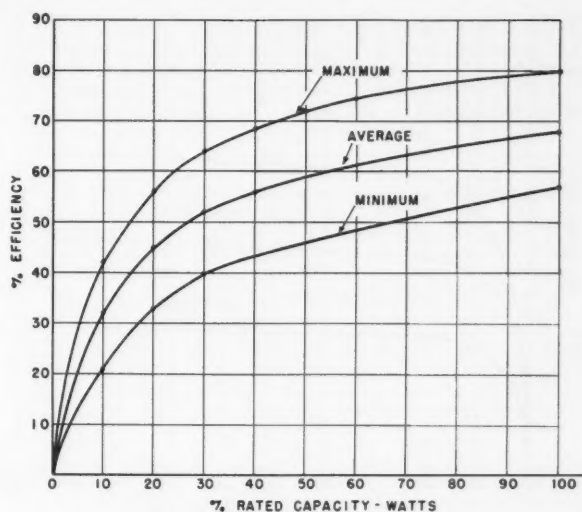


Figure 1—Efficiency curves for 19 tungar rectifiers used for cathodic protection of underground cables.

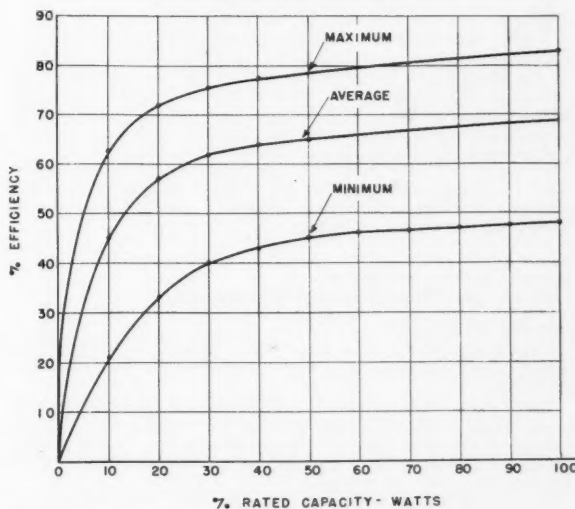


Figure 2—Efficiency curves for 20 selenium rectifiers used for cathodic protection of underground cables.

at less than one half their rated capacity. From the curves obtained it is estimated that a 10 percent increase in efficiency in the electronic type and approximately 5 percent in the selenium type would be obtained by using rectifiers at their full rated output capacity. In the case of copper oxide rectifiers there would seem to be little to be gained in operating them at their rated capacity as compared with 50 percent capacity.

Of the three types tested, selenium units operating at near rated maximum output are considered to be the most satisfactory from overall initial costs and maintenance standpoints.

#### Interference Filters

There is a need for a proper filter in the DC side at some rectifier locations. The absence of the filter may result in noise in telephone circuits and interference to radio and television reception. A suggested condenser is rated at 4MFD 600 volts for use across the DC output. It appears a great many rectifiers are installed without filters. No reference has been made to choke-coils installed in the positive or negative DC lead.

#### Surge and Lightning Protection

Some use is made of open space cutouts in drainage connectors and they have been found satisfactory.

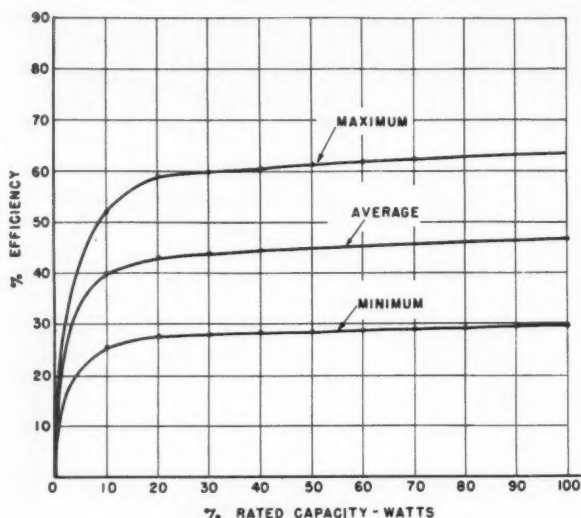


Figure 3—Efficiency curves for 12 copper oxide rectifiers used for cathodic protection of underground cables.

Unless rectifiers are properly fused and protected against lightning, maintenance difficulties are likely to be experienced. It has been found desirable to provide fusetrans (slow acting fuses) in the input leads to rectifiers, and pellet type protectors on both input and output sides of the rectifiers. The pellet protectors, which are self healing, will operate when a lightning discharge occurs over the supply circuit or on the output side of the rectifier, thus protecting the equipment. The fusetrans will operate only when sustained abnormal currents are present, hence frequent fuse operation due to abnormal current is minimized.

#### Insulating Joints Are Used To Mitigate Adverse Electrolysis Effects

##### Communication Cables

Insulating joints have been used to isolate underground dips in aerial cables so that magnesium anodes would be more effective.

Insulating joints are used to break up the cable route when a protected cable transverses a steel or reinforced concrete bridge. Joints are placed on each side of the bridge and an insulated copper wire spans the isolated section to provide protection current continuity.

Insulating joints are placed in all cables entering central office buildings. All cables entering subscribers buildings, i.e., underground all the way from the central office to building terminal, have insulating joints installed (new and existing cables).

One company reports that insulating joints in aerial cables are placed only when current is being picked up from water or gas pipes. If a water pipe ground exists and the aerial exposure is short, or if several water pipe grounds exist an insulating joint is placed on the pole at the junction of aerial cable and underground cable. Otherwise, the joint is placed in the aerial entrance to the building, preferably on

the wall or just inside the building. For noise and protection reasons, ties are sometimes made between aerial cable sheaths and the multi-grounded power system neutrals. Insulating joints sometimes are placed at the aerial underground junction to separate the underground cable from such grounded aerial plant.

They are used also on poles in non-stray current areas between aerial and underground cables to prevent the flow of current between the aerial and underground cables. The use of insulating joints are avoided in underground plant where they are subject to immersion.

Insulating joints have been placed to stop the flow of strong DC picked up on cable sheaths from street railways. Cable manufacturers design and furnish insulating joints when specified by users.

In general, for maintenance reasons, insulating joints are always a possible source of trouble and their number should be kept at a minimum. However, intelligent use of insulating joints increases the life of the underground plant and lowers the operating and maintenance cost of any protective system.

##### Power Cables

Sheath-insulating joints find less application for corrosion protection of power cables than for communication cables. This results from the need to provide electrical continuity for conducting heavy currents during cable faults. When insulating joints are installed, special provisions should be made for assuring electrical continuity during faults by providing such equipment as gaps, resistors, bonds or grounding connections.

Insulating joints are installed in some high voltage cables supplying DC railway substations to prevent excessive DC fault currents from burning the cable sheaths and for electrolysis protection.

Insulating joints are used in high voltage cables to separate the sheaths from copper ground beds of switching and substations in order to reduce the galvanic corrosion and to increase the effectiveness of cathodic protection. The joints are shunted by gaps, or control resistors of sufficient capacity to conduct fault currents.

Insulating joints are installed for stray current control of cables installed in railroad tunnels or in bridge or river crossings. In such cases an insulated conductor spans the isolated section to provide continuity for fault current.

Insulating joints or insulated potheads are used in connection with cathodic protection of pipe lines and pipes of pipe-type cables.

Apart from their purpose in corrosion protection, insulating joints find application in reducing alternating currents induced in the sheaths by the conductor current under normal operating conditions. This reduces the heating of the cable and permits larger conductor currents to be carried.

Insulating joints are installed in the sheaths of single conductor cables of multi-phase circuits wherein the cables are installed one per duct. In the case of three phase circuits, continuity for fault currents is provided by bridging the insulating joints with sheath bonding transformers or with cross bonding. These arrangements reduce the flow of induced currents caused by normal operating currents without jeopardizing continuity for fault currents or for cathodic protection currents. The spacing between insulating joints, usually one or two duct sections, is selected to prevent abnormally high sheath voltages during the fault and to limit the induced sheath voltage under normal conditions to values of about 12 to 15 volts, which will not result in AC electrolysis.

##### General

Communication companies generally use insulating joints for corrosion control, whereas power companies with one or two exceptions, only sparingly.

##### Protective Coatings

Protective coatings are being specified for new cables with the knowledge that such coatings will permit existing cathodic protection systems to operate with little or no change in their present layout. If a cathodic protection system is required in the area where all cables are provided with coatings, corrosion control can be provided by specifying a lower output for the cathodic protection system than in a plain lead cable area.

Wrapped cables will permit the use of magnesium ribbon in a spare duct to provide the cathodic protection of the lead sheath. Longer life of the magnesium is usually affected by moving the ribbon a foot or so every 6 to 12 months.

Cathodic protection systems usually are designed to provide for complete corrosion control in a certain section or area which would include undetected holidays or future deterioration of the sheath coating.

TABLE 1—Summary of Rectifier Capacities and Efficiencies

| Rectifier Type         | No. Tested | % Capacity Range              | % Efficiency Range           |
|------------------------|------------|-------------------------------|------------------------------|
| Electronic<br>(Tungar) | 7          | 6.7 to 25.0                   | 26.1 to 49.5                 |
|                        | 6          | 30.0 to 50.0                  | 50.5 to 69.0                 |
|                        | 6          | 50.5 to 73.0                  | 46.7 to 71.0                 |
|                        | Total 19   | 6.7 to 73.0<br>33.8% (Mean)   | 26.1 to 71.0<br>54.2% (Mean) |
| Selenium               | 9          | 2.1 to 25.0                   | 21.2 to 60.1                 |
|                        | 9          | 30.0 to 50.0                  | 27.2 to 69.0                 |
|                        | 3          | 51.0 to 102.5                 | 54.3 to 83.5                 |
|                        | Total 21   | 2.1 to 102.5<br>33.4% (Mean)  | 21.2 to 83.5<br>58.8% (Mean) |
| Copper<br>Oxide        | 1          | 14.2 to 50.0                  | 47.2                         |
|                        | 7          | 50.0 to 75.0                  | 28.2 to 52.5                 |
|                        | 4          | 90.0 to 150.0                 | 46.3 to 66.3                 |
|                        | Total 12   | 14.2 to 150.0<br>69.0% (Mean) | 28.2 to 55.3<br>41.8% (Mean) |

To date no detrimental effects on protective coatings in cathodically protected areas have been experienced by the cable using companies.

## Summary of Replies to Questionnaire No. 1

### Abstract

Replies to Questionnaire No. 1 prepared by Task Group T-4B-2 (former TP-16C) of the National Association of Corrosion Engineers on Cathodic Protection of Cable Sheath are summarized herewith. Answers are given to questions relating to the broad application of cathodic protection, isolation and insulation of lead cable sheath in buried or underground environments. Companies replying operate both communication and power cables. From the replies considerable information on techniques, criteria, procedures, instrumentation, design and operating routine is included.

### Introduction

SUMMARIZED in this report are answers to questions concerning six broad areas vital to the cathodic protection of cable sheaths as shown in the summary. Task Group T-4B-2 appreciates the efforts of the 18 companies and electrolysis committees listed below for their thoughtful answers to these questions.

#### Companies Answering First Questionnaire On "Cathodic Protection of Cable Sheaths"

Associated Telephone Company, Limited—Santa Monica, Cal.  
Bell Telephone Laboratories—Murray Hill, N. J.  
Commonwealth Edison Company—Chicago, Ill.  
Consolidated Edison Company of New York—New York 3, N. Y.  
Consolidated Gas, Electric Light and Power Company—Baltimore, Md.  
Dallas Power and Light Company, Dallas Texas.  
Denver Committee on Electrolysis—Denver, Colo.  
Dept. of Water and Power of the City of Los Angeles—Los Angeles, Cal.  
Detroit Edison Company—Detroit, Mich.  
Illinois Bell Telephone Company—Chicago, Ill.  
Michigan Bell Telephone Company, Detroit, Mich.  
New Jersey Bell Telephone Company—Newark, N. J.  
Omaha Public Power District—Omaha, Nebr.  
Pacific Telephone and Telegraph Company, Los Angeles, Cal.  
Philadelphia Electric Company—Philadelphia, Pa.  
Public Service Company of Northern Illinois—Chicago, Ill.  
Public Service Electric and Gas Company—Newark, N. J.  
U. S. Steel Corp.—Pittsburgh, Pa.

### Section A—PROTECTIVE CRITERIA

#### Question A

1. Does your company have a set of rules relative to maximum and minimum allowable cable-to-earth potentials for various types of cables, i.e., plain lead, copper jacketed, tape and wire armored, thermoplastic, jute covered, polyethylene, etc.? If so, will your company submit a set of these limits for study by this committee? Otherwise, will you outline your maximum and minimum cable-to-earth potentials for the various types of cables you have in your plant?
2. Does your company use special methods to avoid cathodic corrosion? If so, will your company submit your method for study by this committee? Otherwise, will you outline the methods you use to avoid cathodic corrosion on your cable plant?

#### Company Number

1. No. On our cathodic protection systems for plain lead cable sheaths we try to keep them about .2 volt negative to a lead electrode.
2. No. We have not had any known cases of cathodic corrosion of lead cable sheaths.
1. No definite rules but in general, a maximum of 0.2 volt is used, dependent upon the cable-to-earth resistance, for lead covered cables in fibre ducts.
2. Attempt to lower the potential of the adjacent, anodic structure or raise the potential of our own structure.

3

1. No. Our Company uses plain lead and steel armored cables.

When applying protection under normal conditions, we strive to maintain between a minimum of  $-0.5$  volts and a maximum of  $-0.75$  volts cable sheath-to-earth potentials.

When the cables are in an acid electrolyte, higher negative minimum potentials are maintained.

Except in dry ducts we apply protection to correct all positive cable sheath-to-earth potentials.

2. To reduce effects of cathodic corrosion, usually caused by deicing salt, we flush our duct lines periodically.

When condition is caused by street railway switch salting, we endeavor to have the street railway company install electric switch heaters.

In some cases we bond to adjacent subsurface structures which are positive to our cable sheaths. This method of receiving current from other structures reduces both the cable sheath-to-earth potentials and the density of current received by the cable sheath through the earth. This method requires careful tests and study regarding the effect of the additional current on the cable sheaths in other areas.

4

1. The telephone companies follow rather closely to the maximum and minimum allowable cable-to-earth potentials as suggested by the American Telephone & Telegraph Company.

The telegraph company tries to obtain a negative to earth potential of .1 volt using a ground electrode of the same material as the cable sheath. This figure is recognized as approximate and their engineers may vary it slightly depending on conditions.

The power company at this time has no established practices regarding maximum or minimum allowable cable-to-earth connections. The various groups of the city and county of Denver that use underground cables depend on the telephone and telegraph companies to protect their plants because the entire underground systems of these users are bonded together.

The Tramway Company which now operates a system grounded near several substations has recently installed some underground feeders both positive and negative, all of which are heavily insulated and to date have not concerned themselves with corrosion problems of these installations. They, however, are cooperating in connection with corrosion problems with other companies since there still exists small stray tramway currents due to their method of grounding.

2. There have only been two or three cases of cathodic corrosion come to the attention of the committee and no special methods have been developed by any of the companies in the committee because of its slight occurrence. Since several of the cases of cathodic corrosion occurred at the time the Tramway Company was using a ground rail return system with very high return currents on the underground cable plant, it appears that most of the cases brought to the attention of the committee will not occur again as the tramway has converted to trolley bus with aerial negative returns, stray currents now being relatively minor and isolated.

One case occurred due to the presence of water containing a large amount of alkali through a single duct of the telephone company. This particular duct has been abandoned due to changes in the outside plant. However, the cable had been in service for over 25 years before the failure occurred.

The use of salt on the streets of Denver has to date been rather slight and no corrosion has occurred which might be attributed to the use of salt.

5

1. No, each case is individually considered.
2. No. Each case of cathodic corrosion failure is individually analyzed.

6

1. Yes. For bare lead min.  $-0.05V$  max.  $-1.0V$ . For all others min.  $-0.05V$  max.  $-1.5V$ .
2. Yes. Polyethylene cable when possible and to reduce the negative potential of bare lead cable to a maximum of  $-0.75V$  in an alkaline electrolyte.

7

1. No, but we generally attempt to keep the lead sheaths less than one volt negative and not over 0.15 volt positive, depending on the conductivity of the electrolyte.
2. Rectifier currents are limited to keep sheath potentials less than 1 volt negative.



8

1. Our underground plant consists mostly of plain lead covered cables although we have some buried jute covered cable and a very small amount of armored cable. A small amount of our plant is polyethylene jacketed cable. We consider positive potentials greater than 1/10 volt as hazardous and where the potentials exceed minus .5 volt in the presence of salt, we become concerned. However, some failures have occurred where the potentials were of the order of minus .2 volt. We depend upon 24 hour recording meter charts to determine the need for corrective measures.
2. For many years we employed a grease to cover cables which have been perforated by cathodic corrosion. Cables so treated have not been known to fail a second time where the grease was applied. Because of the damaging effect of such grease on polyethylene jacketed cables we are discontinuing its use. Rather than repair, cables are withdrawn from the ducts, we prefer to employ corrosion protected cables or polyethylene jacketed cables for the replacement. This is, however, often controlled by supply conditions.

9

| 1. Cable Type         | Pos.V. | Neg.V. |
|-----------------------|--------|--------|
| Lead .....            | .15    | .6     |
| Copper Jacketed ..... | —      | —      |
| Tape Armored .....    | .15    | .85    |
| Thermoplastic .....   | —      | —      |
| Jute Protected .....  | 1.5    | 1.5    |

2. No.

10

1. No. However, in stray current areas it is aimed to maintain the cable at about .5 volts negative to ground to earth using a lead plate or lead chloride half cell to contact the earth.
2. Yes. We flush duct with water where there is evidence of alkaline precipitation which is produced by the cathodic process. Also, we treat manhole hardware with insulating paint at locations where there is an excessive precipitation of alkali.

11

1 and 2, No.

12

1. No. For lead sheath cable 0.1V max. 0.5V min.
2. All underground utilities in Omaha control corrosion by bonding and drainage to street railway substations. The power district also bonds and grounds lead sheath cables at manholes and buried splices.

13

1. No. Our experience indicates that the magnitude of current discharge per foot of cable limits the life of the cable in anodic areas. See Gorman's paper<sup>2</sup> on duct surveys and the interpretation of results of duct surveys.

In respect to corrosion in cathodic areas, we feel that a pick-up of 10 milliamperes or more per foot of cable may result in cathodic corrosion. This criterion is based on studies reported by Herman Halperin.<sup>4</sup>

2. No. So far as can be determined we have had only two cable failures from cathodic corrosion. In the first case, a cable installed in a tile duct in an underwater railway tunnel failed in 1932 after approximately 10 years of service. Duct surveys showed the cable sheath to be 0.8 volt negative with respect to a lead electrode in the vacant duct. The cable sheath was negative with respect to the railway tracks by 5.0 volts average. Minimum resistance was apparently caused by seepage of saline tide water through the tunnel wall. The current flowing to the sheath (estimated at 40 milliamperes per foot at the worst point) apparently decomposed the saline water electrolytically with the resultant formation of alkali on the sheath. The action of the alkali was to form lead hydroxide which reacted with carbon dioxide to form basic lead carbonate, large quantities of which were found on the corroded cable. The corrective measures in this case were to clean the railway road bed and rearrange the railway negative feeder connections to reduce the potential difference between the rail and cable sheath.

In the second case of cathodic corrosion, a cable in street ducts near trolley rails and elevated structure failed in 1940 after 18 years' operation. The duct survey showed the cable sheath potentials to be 0.5 volt negative with respect to the lead electrode in a vacant duct, 5.5 volts negative with respect to the trolley rail, and 6.2 volts negative with respect to the elevated railroad. The duct resistance was approximately 500 ohms per foot of cable. The cathodic

conditions disappeared when trolley operation was later abandoned.

14

1. No. When a cable sheath is found to be positive to earth or to other substructures, except for short duration, remedial measures are taken.
2. Special drain cables from cable sheaths to the street railway DC generator. In addition, magnesium anodes are used for sheath protection.

15

- 1 and 2. In connection with questions A-1 and A-2, cable-to-earth potential measurements may be made advantageously with the aid of half-cells. Although two varieties, i.e., copper-copper sulfate and lead-lead chloride are used, our interest has centered on the lead-lead chloride half-cell.

16

1. The cable system is made up most entirely of lead covered cable with small amounts having rubber or neoprene jacket and wire armor. The company has no set of rules regarding maximum and minimum cable-to-earth potentials. The policy is to keep all cable sheath potentials as near earth potential as possible. Specific circumstances govern what can be done and what we try to live with.
2. Potentials to earth are maintained as low as possible or install cable with a rubber or a neoprene jacket. Controlled drainage is used to control the cable to earth potentials.

17

1. No. Practically all the cables in the underground plant are bare, lead covered, or lead covered with a neoprene jacket over the lead. The jacketed cables are bonded to the bare cables and operate under the same potentials. We attempt to maintain the sheaths between 0.2 and 0.5 volt negative with respect to earth. Due to stray railway current conditions, sheath potentials vary from a few tenths of a volt positive to earth in some areas and as much as 2.0 volts negative to earth in other areas.
2. Most cathodic corrosion has occurred in high negative areas in the vicinity of street railway track switches where salt is used to prevent freezing of the switches during the winter months. Duct surveys are used to determine the locations where cathodic corrosion of the cables is occurring. Based on duct survey data, approximately 60 excavations have been made adjacent to track switches, the conduits broken out, the corroded cables repaired in place, the conduits restored and the salt-contaminated fill from around the conduits replaced with clean sand. These excavations have varied from 30 to 80 feet in length. At some locations where there are a series of track switches such as the entrances to car barns, the bare lead covered cables have been replaced with cables having neoprene jackets over the sheaths. At a few locations the negative potentials of the sheaths have been reduced by improving the negative returns of the street railway systems.

18

1. No. Would be glad to submit a set of limits if developed.
2. We have used drainage bonds through reversing switches to railway rails and negative bus of their substations only.

19

1. We have no limits for DC sheath potentials but have established induced 60-cycle sheath potentials of 12 to 20 volts to ground, depending upon local conditions. In general, a maximum limit of 20 volts 60 cycles-to-ground causes no noticeable corrosion, but most users prefer something in the order of 12 to 15 volts. This applies to bare lead sheath in ducts. When the sheath is insulated permanently with a durable jacket, we allow an induced 60-cycle voltage as high as 50 to 75 volts to ground or any DC voltage that might be encountered due to stray currents, etc.
2. As previously stated, manufacturers rarely if ever recommend specific methods of corrosion mitigation but leave the diagnosis to the users. We do recommend an insulated jacket over the bare lead sheath whenever there is any question of corrosion trouble.

## Section B—RECTIFIER GROUND BED DESIGN AND LOCATION

### Question B

1. Does your company have a set of rules relative to the design and placement of the rectifier ground bed for the protection of lead sheath cables?
  - a. For a point type ground bed.
  - b. For a distributed type ground bed.

If so, will your company submit these rules for study by this committee? Otherwise, will you outline the rules you use relative to the design and placement of rectifier grounds?

2. Does your company have a set of rules relative to interference measurements with other substructures before installing rectifier ground beds? If so, may they be studied by this committee? Otherwise, will you outline the methods you use to minimize interference with other substructures when placing rectifier ground beds?

**Company**

- 1
- 1.a. For a point type ground bed.

Our anode consists of 100 foot long, 135 pound used railroad rail buried six feet deep and encased in a backfill two feet square around the rail consisting of a mixture of soil and approximately 5 pounds of salt (sodium chloride) per cubic foot mixed in a cement mixer and poured in like cement. After this hardens, we place a 6-inch layer of medium size rock on top and then the balance of the trench is backfilled with the earth removed originally during excavation.

Standpipes made from 4-inch concrete duct, perforated near the bottom, extend from the rail to the surface of the ground for future watering of the anode bed. The anode lead is connected to the 100-foot rail at four places by means of four cups which are filled with ozite compound to protect the connections from the action of the anodic current leaving the iron rail.

In one installation we used coke breeze in place of the salt soil mixture.

The anode is placed as far away from the cable line as practical, usually about one or two city blocks.

- b. For a distributed type ground bed—Answer, None.
2. None. We try to locate the rectifier ground bed at least 50 to 100 feet from any other substructure.

- 2
1. We do not have any rectifiers operating on our underground cable plant.

- 3
1. and 2. As yet our company has not found it necessary to use ground beds for cathodic protection.

- 4
1. No practices or sets of rules relative to rectifier ground bed placement has been used or developed by any of the companies in the committee and at present there are relatively few rectifiers in use by the member companies except those used by one of the telephone companies, none of which are in the Denver area. The telegraph company is at present using a small rectifier in the downtown Denver area, using the tramway grounding bed for distribution. It appears that some rectifier installations will be required in the future in Denver to remedy certain slight positive conditions in the downtown area.

2. Interference with the substructure or plant of other companies when an installation is made by any particular member of the committee is studied by the Denver Committee on Electrolysis and no rectifiers or other corrosion protective devices are installed without the knowledge of this committee.

- 5
1. No. Each case separately engineered.

2. No. Each case individually considered. When a rectifier installation is contemplated, a cooperative survey is made jointly by interested parties to assure a minimum of interference.

- 6
- 1.a. Yes.

b. Has been used in the form of a duct anode. Until recently 13-inch OD or larger diameter steel pipe has been used as the anode, but due to the cost and difficulty in obtaining iron pipe, carbon or graphite, 3x60-inch anodes are being used on the basis of an anode per ampere of expected output.

The control cable used for distributed anode in a duct is but one size. On numerous occasions good bare lead-sheathed junk cables have been used as anodes in a distributed system within the duct.

2. Yes. Before a cathodic station is designed, a tentative location for the anode is chosen and then all interested substructure operators are invited to a joint field test. Ground rods are driven at the chosen location, then a motor generator set is used to discharge various amounts of current

into the ground while recording clocks, which had been set out previously, record the various changes of the cable-to-earth potential. The other utilities do likewise to determine the amount of interference. From these tests are determined the minimum current for proper protection of the telephone cables and also if joint use with other substructure operators would be economical and feasible.

- 7
1. No. We design each installation for the job so as to achieve the maximum spread possible with a minimum of interference on other structures.

2. No set rules but arrange for mutual testing of both systems to insure no concentration of hazard. If such hazards cannot be avoided by proper design and location of ground beds, bonds are made with the proper values of resistance to secure a satisfactory division of current.

- 8
1. We intend to follow the specifications outlined in the Bell System Practices on this subject which is prepared by the A. T. & T. Company.

2. We have very few cathodic protection systems and when any are proposed we notify all the concerned utilities for joint tests through the Chicago Joint Electrolysis Committee.

- 9
1. a. Yes.

- b. Not as yet.

2. Yes.

- 10
1. No. All new ground beds employ graphite or carbon anodes and graphite backfill. We are guided by the rules furnished by the manufacturer of the anodes. All of our ground beds are of the point type.

2. The company submits plans for proposed ground bed installations to the Detroit Committee on Electrolysis. The committee arranges for joint tests with all companies or utilities whose underground plants might be exposed to corrosion due to the proposed installation.

- 11
1. and 2. No.

- 12
- Rectifier ground beds have not yet become a problem. If and when they do, the situation will probably be handled by the electrolysis committee.

- 13
1. No. We have three installations of scrap cable anode installed in the same duct bank as the operating cables under protection. The voltage impressed between the scrap cable and operating cable is in the order of 4.0 volts, obtained from a rectifier. The current is considered to flow electrolytically from the anode to the operating cable without interfering with surrounding metallic structures.

One cable section approximately 250 feet long is protected by a scrap rail anode which consists of 20 rails 6 feet long, driven vertically into the earth in a line a few feet from the cable duct line. The tops of the rails are welded to a horizontal rail which is energized at 6 volts positive potential. Interference with other structures is reduced by the close spacing between the rails and cable system.

2. No. Our practice is to notify other companies operating underground cables and pipes of the proposed installation of cathodic protection and to make tests jointly with and without the cathodic protection operating.

- 14
1. a. Rectifiers used only in vicinity of two power plants—mainly for underground pipe protection provided. Point type ground beds used. Each installation individually engineered.

2. Contact is made with interested party and problem worked out.

- 15
1. A technical paper<sup>5</sup> published in Corrosion may have information to be included with the data you will receive in reply to question C-2.

- 16
1. No. The few in use were designed to fit the specific situation.

2. The only rule relative to interference measurements with other structures before installing rectifier ground beds is to meet with the interested people to work out points of mutual interest.

17

1. a. and b. No. Each rectifier installation is designed to correct conditions at a specific location. Test data usually determine the type of installation to be made.
2. All rectifiers installed for the prevention of corrosion of the substructures in the urban area are discussed in the meetings of the joint electrolysis committee of the various utilities companies and the interested companies are invited to make joint tests before and after the installations are made. Preliminary tests usually will determine if the installation will affect other nearby structures. If interference does occur arrangements for interconnections are worked out and installed.

18

1. a. and b. No. We have not as yet provided cathodic protection for any cable.
2. Would coordinate with engineers of other utilities with underground structures in the area before making the installation.

19

1. and 2. This practice is left to the users after diagnosis.

### Section C—INSTALLATION OF GALVANIC ANODES FOR CATHODIC PROTECTION OF CABLE SHEATHS

#### Question C

1. Will you outline here any comments you may have regarding the use of anodes for the cathodic protection of cable sheaths?
  - a. Aluminum
  - b. Magnesium
  - c. Zinc

#### Company Number

1

1. We have had no experience in the use of galvanic anodes such as aluminum, magnesium and zinc for the protection of lead cable sheaths. We are making some test installations of packaged magnesium anodes to be installed in the earth below the manhole floor to protect the lead cable sheaths. Experiences of others have shown that magnesium anodes do not give sufficient protection where stray railway currents are present on the cable sheaths.

2

1. a. Zinc anodes have been utilized in two cases. Conditions in these areas were corrected before any conclusive data on the zinc anodes could be obtained.

3

1. Our company's cable plant is located in a stray current area. We have not tried to use galvanic anodes to protect our cable sheaths.

We use magnesium anodes to cathodically protect submerged underground transformers and other manhole equipment. The use of zinc anodes for this type of installation was not successful due to the zinc becoming polarized.

4

1. One telephone company has an installation of magnesium anodes protecting bare lead sheath buried cable. This cable was installed in 1926 with merely a coat of asphalt paint on the sheath. In the late 1930's and early 1940's numerous repairs were required due to corrosion. In 1948 it was decided to replace the cable, but reconsideration was given to the installation of cathodic protection to determine if the life of the plant could be extended. Magnesium anodes were placed and to date no further openings have occurred in this cable plant and it appears that many more years of life may be expected under present conditions.

Several magnesium anodes have also been installed on underground dips where positive conditions existed in buried cable and appear to satisfactorily protect the plant. No more anodes have been used for the cathodic protection of cable sheaths in the Denver area. At this time, though, several areas are under construction.

5

1. a. Not used.
- b. Magnesium ribbon-type anodes pulled into vacant ducts were found unsatisfactory for galvanic protection of cables in adjacent ducts in the same duct bank. Anode consumption was very non-uniform, the ribbon in dry

spots being unable to contribute current to adjacent wet areas. In one case it was found that after about 20 percent of the anode was consumed, practically all protection was lost.

c. Not used.

6

1. Magnesium anodes have been used extensively in our area with very satisfactory results. The anodes have been buried both beneath the manhole floor and outside the manhole. They also have been used on buried cable with good results. However, the use of magnesium anodes is limited when the number of cables in a run exceeds three.

No aluminum or zinc anodes have been used in our area.

7

1. a. We feel that aluminum anodes are satisfactory but do not use them as we prefer the greater driving potential of magnesium.

b. We use magnesium anodes because we prefer their high driving potential and have found that they have no tendency to stifle themselves.

We limit the current on magnesium duct anodes to avoid severance of the ribbon.

c. Our experience with zinc shows that it becomes stifled within a few months due to the formation of a heavy zinc carbonate.

8

1. a. No aluminum anodes are used in our area.
- b. We have 12 installations of magnesium anodes. They have been most effective on isolated sections of cable.
- c. No zinc is now in service although we have had one such installation.

9

1. a. No experience.
- b. Field trials in process
- c. Not satisfactory.

10

1. We use only a few (less than one hundred) galvanic anodes and they are of the magnesium type. Most anodes are installed in manholes without backfill. Some are installed outside the manhole when current distribution can be improved. There are a few installations outside the manhole using a prepared backfill where increased current was required.

11

No installations have been made primarily for this purpose. Magnesium anodes are being used to protect steel ground rods at a new plant location. They will probably afford some protection to cable sheaths.

12

Galvanic anodes have not yet been used on lead sheath cable. It may be necessary in the future to resort to magnesium anodes for isolated cables.

13

We do not use galvanic anodes for the cathodic protection of cable sheaths. Large currents would be required because the sheaths of the cable system are in electrical contact with the bare water piping through grounding connections. Hence, a large number of anodes would be required. It is felt that galvanic anodes can be applied to protect portions of cables which are insulated from adjacent sections by insulating joints. However, sheath insulating joints are not used on our system except in certain special cases described below under question F.

14

A limited number of magnesium anodes are in use only a short time.

15

No suggestions.

16

1. Galvanic anodes for the protection of cable sheaths have been used only in a rather experimental manner and this in connection with lead sheaths covered with a conducting Neoprene (carbon loaded Neoprene) jacket. An installation is to be made where magnesium anodes are to be used to protect the steel pipes of pipe line cable.

17

1. We have had very little experience with galvanic anodes. The few installations made using magnesium and zinc have proved satisfactory where installed. We have not used aluminum. The design of our underground plant is such that at most locations, the installation of galvanic anodes is not feasible.



- 18  
1. Magnesium anodes are being used by the Bell Telephone Company on its intercity cable sheaths in runs joint with our local cables.

- 19  
1. Left to the users.

#### Section D—RECTIFIER CHARACTERISTICS RELATIVE TO LEAD SHEATH CABLE PROTECTION

##### Question D

1. Briefly outline your experience with various types of rectifiers.  
a. Selenium, copper oxide, tungar, others.  
b. Efficiency  
c. Interference filters  
d. Surge and lightning protection

##### Company Number

- 1  
1. a. All our rectifiers are of the selenium type and seem to give good service.  
b. No tests.  
c. None.  
d. None.
- 2  
1. a. No rectifiers in use at present. Copper oxide rectifiers were experimented with, but their use abandoned.

- 3  
1. a. We use both copper oxide and selenium type rectifiers. We have had unfavorable experience with two copper oxide rectifiers using forced ventilation which was caused by corrosive air and dirt accumulation damaging the stacks.  
b. Selenium—65 to 70 percent.  
Copper oxide—No figures.  
c. Have not found necessary to use.  
d. Surge-condensers for induced AC surges caused by switching. Lightning—AC input side—General Electric Pellet Service Protector Model 9LA15A2. DC output side—thyrite arresters.

- 4  
1. No rectifiers have been used in the Denver area to give lead sheaths cable protection with the exception of the one recently installed by the telegraph company which was included under "C."

- 5  
1. a. We have used selenium and copper oxide rectifiers and have found them to perform satisfactorily.  
b. Under proper conditions, rectifiers have been found effective in protecting lead cable sheathing.  
c. We have no experience with such filters.  
d. We have no surge or lightning protectors installed on rectifier installations. No trouble attributable to surges or lightning has been experienced on rectifier installations.

- 6  
1. a. Selenium, copper oxide and tungar rectifiers have been used to good advantage. The tungars have given trouble due to noise interference necessitating the installation of filters at the rectifier installations.  
b. The efficiency is about 75 percent.  
c. No trouble has been encountered with either the selenium or copper oxide rectifiers. However, all rectifiers now being installed are selenium.  
d. No surge or lightning protection is used in our area.

- 7  
1. a. We have had very satisfactory experience with selenium rectifiers. Copper oxide rectifiers have had a tendency for edge corrosion on the discs and, in general, require more maintenance than other types. Tungar rectifiers are used in instances where a high voltage (75 volts) is necessary.  
b. We do not consider rectifier efficiency.  
c. Interference filters are used on tungar units only.  
d. We feel that arresters or gaps should be provided for both the rectifier source, when such source is overhead wires and for the rectifier DC service.

- 8  
1. a. We have had one tungar rectifier but it is not in use at

present for lead sheath protection. There are six copper oxide rectifiers but none of the selenium type.

- b. There have been no efficiency tests made on these rectifiers.  
c. Filters are used on our installations.

9

1. a. Selenium—field trial.  
Copper Oxide—successful use.  
Tungar—no new installations to be made.  
b. Fairly good, except tungar.  
c. Always used.  
d. Required in all outdoor installations.

10

1. a. Tungar rectifiers were used in early installations. In later installations selenium rectifiers have been employed except in cases where it was necessary to reuse tungar rectifiers. The selenium rectifiers are preferred because they require little or no maintenance, while the tungar rectifiers require some maintenance.  
b. Selenium rectifiers are assumed to be more efficient than tungar rectifiers although we have made no tests and have no data to prove this.  
c. We have found that there is a need for a proper filter in the DC side at some rectifier locations. The absence of the filter results in noise in telephone circuits and interference to radio and television reception.  
d. The lightning protection involving Dunco relays installed on some earlier rectifiers were sources of trouble. Our recent installations have been made with only the protection generally used by the power company. There has been no damage to those installations due to lightning.

11

Rectifiers are now in use in several locations to protect cable sheaths. Each present installation has been handled by individual plants and none have been in use long enough to provide much helpful data.

12

No rectifier experience to date.

13

1. Have had 20 years of satisfactory experience with a copper oxide rectifier installed in one station for cathodic protection of cable sheaths in 1932. Subsequently, copper oxide or selenium rectifiers have been installed at three locations on the cable system and at three locations on the gas system. At none of these locations have lightning or telephone interference troubles been encountered. No provision has been made for lightning or interference protection equipment at the rectifier.

14

1. a. Selenium rectifiers used in vicinity of two power plants.  
b. Operation satisfactory based on relatively short experience.

15

1. A technical paper<sup>2</sup> was delivered before an NACE Annual Conference in Galveston, Texas contained a large variety of data showing the features of tungar, copper oxide and selenium rectifiers as experienced on cables of the Long Lines Department of the American Telephone and Telegraph Company.

16

1. The installations are too limited in number and size to have experience of any value regarding rectifier characteristics.

17

1. We use both selenium and copper oxide rectifiers and under general service conditions, the efficiency of the two types appears to be about the same. Filters have not been used and no extra precautions have been taken to prevent damage of the units from surges and lightning.

18

1. No. experience.

19

1. Left to the users.

#### Section E—INSULATING JOINTS AS USED TO MITIGATE ADVERSE ELECTROLYSIS EFFECTS

##### Question E

1. Briefly outline what use your company makes of insulating

joints in cable sheaths to control corrosion.  
a. Aerial, underground, buried cables.

#### Company Number

1

1. a. Occasionally we use insulating joints in lead cable sheaths where it is necessary to isolate sheath currents on aerial and underground cables. In the 138 Kv cable system, which has three single conductor cables for each circuit, we have an insulating joint in each cable in each manhole. However, these joints are bridged across with a sheath bonding transformer to control the induced AC sheath currents. These sheath bonding transformers offer practically no resistance to the DC sheath currents so that the overall effect is a continuous sheath for the cathodic protection current. We have practically no cables buried directly in the earth.

2

1. a. We have not used insulating joints for the purpose of corrosion control for about 25 years. They were used only on single-conductor cables, to lower induced current.

3

1. a. Do not use.

4

1. a. These insulating joints have been used to isolate areas where cathodic protection such as the one mentioned in "D" has been used. They have also been used to break up conducting paths in the stray current areas. These joints have been placed in aerial, underground and buried cables.

5

1. a. Do not use.

6

1. a. Insulating joints being placed in all cables entering central office buildings. All cables entering subscribers buildings, i.e., underground all the way from the central office to building terminal, have insulating joints installed (new and existing cables). Insulating joints in aerial cables are placed only when current is being picked up from water or gas pipes. If a water pipe ground exists and the aerial exposure is short, or if several water pipe grounds exist an insulating joint is placed on the pole at the junction of aerial cable and underground cable. Otherwise, the joint is placed in the aerial entrance to the building, preferably on the wall or just inside the building.

7

1. a. **Aerial Cables.** Insulating joints not used generally in our aerial cables. Isolation from cathodically protected underground sections generally is made by installing the insulating joint in the last manhole before the aerial cable riser.

**Underground Cables.** Insulating sleeves are used in our underground lead sheathed cables to separate the sheaths from switching and substations copper ground beds to reduce the galvanic couple and sometimes to increase the effectiveness of rectifier installations.

8

1. a. Insulating joints are used at nearly all building entrances, aerial or underground. For noise and protection reasons, ties are sometimes made between aerial cable sheaths and the multi-grounded power system neutrals. Insulating joints are sometimes placed at the aerial underground junction to separate the underground cable from such grounded aerial plant.

9

1. a. Used in all building entrances in areas that have any adverse history.

10

1. a. Insulating joints are used at building cable entrances to separate telephone cable plant from pipe structures. They are used also on poles in non-stray current areas between aerial and underground cables to prevent the flow of current between the aerial and underground cables. We avoid the use of insulating joints in our underground plant where they are subject to submersion.

11

1. a. Insulating joints in lead covered underground cables are being used on new installations to isolate steel grounding systems from copper grounding systems.

12

1. a. The telephone company uses insulating joints on services. Insulating joints have not been used in power cables to date.

13

1. a. Insulating joints and cross-bonding are installed in single conductor cable of three-phase feeders in which the phase cables are installed in separate ducts. These insulating joints reduce circulating sheath currents and thus allow the current carrying capacity of the cable to be increased. The spacing between insulating joints is designed to prevent abnormally high sheath voltages during transient conditions (cable faults), and to prevent high AC electrolysis during normal load periods.

Insulating joints are installed in high voltage cables supplying some railway substations to prevent excessive DC fault currents from burning the cables, and for electrolysis protection.

Insulating joints are installed where needed in conjunction with drainage cables in a few locations in order to obtain satisfactory correction of electrolysis conditions caused by stray railway currents.

From the above it seems that insulating joints are used for corrosion control on the underground cable system in a few cases only. Sheath continuity for fault currents is indispensable for operating reasons. This rules out the widespread use of insulating joints for electrolysis control.

14

1. a. None.

15

No comment.

16

1. a. There are no insulating joints in the lead cable system for the control of electrolysis effects. Alternating current power station ground buses (which are connected to cable sheaths) should be isolated electrically from the railways' DC negative system for control and measurement of earth currents and potentials between them.

17

1. a. Insulating joints are not used generally in the sheaths of the cable plant for the mitigation of electrolysis. The continuity of the sheath circuit is maintained to provide a path for fault current in event of a cable failure.

18

1. a. We have placed insulating joints to stop the flow of strong DC picked up on our cable sheaths from street railways.

19

1. a. Cable manufacturers design and furnish insulating joints when specified by users.

### Section F—PROTECTIVE COATINGS FOR LEAD CABLE SHEATHS TO MITIGATE SHEATH CORROSION

#### Question F

1. What use does your company make of protective sheath coverings?  
a. On original installation.  
b. On cable repairs, either caused by electrolysis or mechanical damage.

#### Company Number

1

1. None. However, we may find some use for them in the future.

2

1. Neoprene-jacketed cable is used:  
a. On original installations where corrosive conditions are known to exist.  
b. To replace cable that has failed due to corrosion.

3

1. Our company uses a double leaded cable in our most severe corrosive areas where the usual mitigation methods are not entirely effective. This type cable consists of two lead sheaths with two layers of asphalt impregnated tape in between the two sheaths.

- a. Yes.  
b. Yes. When caused by severe electrolytic or chemical action.

4 The telephone companies have made use of protective sheath coverings on original installations and on replacements in bad stray current areas. The power company has installed Neoprene covering. The city and county of Denver cable installations for traffic control uses Neoprene covered cables exclusively.

5  
1. a. In locations where known severe electrolysis conditions exist or are to be expected, neoprene-jacketed cable is used.

b. In areas of severe galvanic corrosion attack, Neoprene jacketed cable is used to replace failed cables. Replacement of cables is made with Neoprene-jacketed cable to prevent mechanical damage in old duct banks where severe scoring of unprotected lead sheathing would be expected.

6  
1. a. Kraft paper and coal tar (corrosion protected) for toll cables and polyethylene for exchange and trunk cables.  
b. If the damage was caused by electrolysis and the cable must be replaced, corrosion protected cable is used for toll cables as no other covering is available at the present time and for exchange or trunk cable alpeph or stalpeph (polyethylene coverings) is used. If mechanical damage occurs no protective coverings are used.

7  
1. a. Original installations: Protected sheath cables are used on original installations only in locations known to be subject to corrosion.  
b. Cable Repairs: Protected sheath cables for repairs or replacement are only used in areas where experience or duct surveys indicate a corrosion hazard exists.

8  
1. a. We employ jute covering or polyethylene jacketed cables for buried installations and use corrosion protected or polyethylene cable where cathodic corrosion has caused failure in cables in conduit.  
b. As noted previously we have in the past employed a grease following cable repairs where salt was present. Litmus or similar papers generally used to determine the presence of alkaline conditions.

9  
1. a. Used where potential measurements or past history indicate adverse conditions.  
b. Used when failures are caused by electrolysis.

10  
1. a. Jute protection is used on all buried cables. Corrosion protected cable and alpeph cable are used in corrosion hazard locations.  
b. Protected cable is not generally used on repair jobs where short lengths of cable are involved. However, it is used in corrosion hazard locations where complete section replacements are involved.

11  
1. On new installations, Neoprene jacketed cables are being used.

12  
1. A Neoprene hose jacket over the lead sheath has been used on the original installation of important circuits where extremely corrosive conditions existed. The same type of cable has been used to replace cable damaged by corrosion in a salt environment.

13  
1. Protective coatings are used in designated areas which are known from experience or electrolysis surveys to be corrosive. Less than 10 percent of the cable system is considered to be installed in corrosive areas.

Generally, the protective coating consists of the application of corrosion preventive grease to all surfaces of the cable as it is pulled into the duct. The grease is a petroleum base compound. Approximately 25 pounds of grease are required for 100 feet of 3-inch diameter cable. Proportional amounts are used for smaller cable. This method of protection which was inaugurated in 1941 has appreciably reduced the corrosion failure rate in areas where it has been used. However, the grease protection is inadequate in the more severe corrosion areas. In the more acute corrosion areas, a lead sheath, reinforced Neoprene jacketed

cable is installed for corrosive protection. This has given satisfactory service in the relatively few areas where it has been used.

14  
1. a and b, None.

15  
1. No comment.

16  
1. a. Protective coatings are used on cables on original installations where conditions are known to be or believed to be detrimental to bare lead. A rapid method of determining if there are detrimental conditions is desired.  
b. Protective coated cables have been used to replace cables that were damaged by chemical action or cathodic corrosion but never from electrolysis action. Cable sheaths are given protection from mechanical damage in certain manholes.

17  
1. In some prescribed areas, lead covered, Neoprene jacketed cables are used for all new installations and all replacements of cables above a stated voltage rating. Jacketed cables are installed and bare cables replaced with jacketed cables at other locations on the system when specified by the corrosion engineers in order to prevent corrosion of the sheaths.

18  
1. a. For mechanical protection only of cable buried without conduit.  
b. For mechanical protection only.

19  
1. The use of protective jackets over bare lead sheath appears to be growing, judging from orders received. Different types and qualities of such insulating jackets are available, the cost being in proportion to durability and quality. In general, the cotton tape reinforced Neoprene jacket is recognized as the best, although the glass tape reinforced Neoprene jacket is being perfected and has greater mechanical strength.

## Summary of Replies to Questionnaire No. 2

### Abstract

Replies to questionnaire Number 2 prepared by Task Group T-4B-2 (formerly TP 16C) of the National Association of Corrosion Engineers on Cathodic Protection of Cable Sheath are summarized herewith. These questions were forwarded to clarify and amplify similar questions in the first questionnaire.

### Introduction

SUMMARIZED in this report are answers to questions concerning four areas originally covered in the first questionnaire. Task Group T-4B-2 appreciates the efforts of the 25 companies and electrolysis committees listed below for their clarifying answers to these more detailed questions.

### General Information

#### Companies Answering Second Questionnaire On: Cathodic Protection of Cable Sheaths

American Telephone & Telegraph Company—Washington, D.C.  
Chesapeake & Potomac Telephone Company, Norfolk, Va.  
Chesapeake & Potomac Telephone Company of Va.  
Cincinnati Gas & Electric—Cincinnati, Ohio  
Commonwealth Edison Company, Chicago, Ill.  
Consolidated Edison Company of New York—New York, N.Y.  
Consolidated Gas, Electric Light & Power Company—Baltimore, Md.  
Dallas Power & Light—Dallas, Texas  
Dayton Power and Light—Dayton, Ohio  
Denver Committee on Electrolysis—Denver, Colo.  
Department of Water & Power of the City of Los Angeles—Los Angeles, Cal.  
Detroit Edison—Detroit, Mich.  
Illinois Bell Telephone—Chicago Division—Chicago, Ill.  
Illinois Bell Telephone—Mid-State Division, Chicago, Ill.  
Iowa Illinois Gas & Electric Company—Davenport, Iowa  
Michigan Bell Telephone Company, Detroit, Mich.  
New Jersey Bell Telephone Company, Newark, N. J.



Northern Electric Company, Lachine, Quebec, Canada  
 Pacific Telephone & Telegraph Company—Los Angeles, Cal.  
 Pennsylvania Power and Light—Allentown, Pa.  
 Philadelphia Electric Company—Philadelphia, Pa.  
 Public Service Company, Maywood, Ill.  
 Public Service Electric & Gas Company—Maplewood, N. J.  
 The Ohio Bell Telephone Company—Cleveland, Ohio  
 Western Union Telegraph—Atlanta, Ga.

## Section A—PROTECTIVE CRITERIA

### Question A

- What criteria does your company employ to determine adequate cathodic protection for
  - Plain lead sheath?
  - Copper jacketed?
  - Tape and wire armored?
  - Thermoplastic?
  - Jute covered?
  - Polyethylene jacketed?
- What limits do you strive to obtain?

### Company Number

- .02 to .04 volt negative to earth.
  - None.
  - None.
  - e, f. These are connected in grid with our lead sheath. No insulating joint.
- .02 negative to .02 positive to earth.
- Almost no cathodic protection of lead sheathed cables.
  - Have no copper jacketed cables.
  - Tape armor used quite generally for street lighting. No protection except its jute and coal tar mastic covering.
  - e, f. Much used for control and lighting cables buried directly in the ground but no checking done.
- See 1, a.
- The cable sheaths to be held just negative to earth when the meter earth contact is made with lead plate of composition similar to the composition of the sheath.
  - No copper jacketed cable in use.
  - Very little in use and then in rural areas. In general the same criteria as in a. above, but with check using Cu SO<sub>4</sub> cell for earth contact.
  - No thermoplastic used.
  - Expect "over lead" is intended, then criteria is the same as for plain lead sheath.
  - Not used.
- Wish to have the lead sheath about 0.2 volts negative to earth.
- 0.1V between cable sheaths and ground (small piece of cable sheath on manhole bottom).
  - None.
  - Only river crossings. No special test.
  - None.
  - Same as plain lead sheath.
  - No test.
- 0.1V or more.
- 1 and 2. No criteria or limits given.
- Our experience indicates that the magnitude of current discharge per linear foot of duct lay cable, (as determined by the duct survey) indicates the probable life of cable. In stray current areas, the amount of drainage current is limited to that value which will reduce the stray current discharge to zero. With the drainage current thus adjusted, there will be minimum fluctuations of sheath-to-duct potential caused by stray current variations. Care is taken not to over-drain the cables in order not to jeopardize the cables of other companies. If cathodic protection is applied in non-stray current areas the anode is placed in or close to the power cable duct bank in order to avoid causing electrolysis on the pipes and cables of other companies. It is felt that satisfactory conditions will result if the resulting sheath potential is slightly negative (0 to 0.1 volt) with respect to the lead duct electrode.

The above answers apply to plain lead sheath cable.

- In stray current areas, we strive to obtain just sufficient

drainage to reduce the sheath to duct voltage fluctuations to zero.

In non-stray current areas we attempt to adjust the protective current from cathodic protection installations to a value such that the resulting sheath potential is 0 to 0.1 volt negative with respect to the lead duct electrode. This should result in a pick-up of less than 10 milliamperes per foot of cable. We feel that currents exceeding 10 milliamperes per cable foot may result in cathodic corrosion of lead sheath.

7

- We measure the cable-to-earth potentials, the cable to nearby structure potentials and the magnitude and direction of sheath currents.
  - c, d, e, f. No experience.
- Generally less than .2V negative. However, we strive for less than .1V negative in critical areas. Positive conditions are tolerated only if there is no sheath current.

8

- No set rules are in use by this company for maximum and minimum cable-to-earth potentials. In stray current areas it has been our aim to maintain the cable at about 0.5 volts negative to ground using a lead plate or lead chloride half cell to contact the earth. In non-stray current areas we use corrosion experience as our criteria for determining cathodic protection.

We have recently adopted the use of copper sulfate half cells to determine cable to ground potentials. Our aim is still to maintain our cable at about 0.5 volt negative to ground in stray current areas.

- Not used.
- Same criteria as for lead sheath cable.
- Not used.
- Jute protection is generally used on buried intercity cables. Buried cables are generally in non-stray current areas and we use corrosion experience to determine protection measures. We have wrapped our jute covered, buried cables with plastic tape at pipe line crossings.
- No cathodic protection has been applied to this type of cable which we use in buried underground and aerial plant.

9

- 55 volt to a lead chloride half cell.
  - None installed.
  - 85 volt to a copper sulfate half cell.
  - None installed.
  - Between —.15 and —1.5 volts to a lead chloride half cell.
  - Same as plain lead sheath.

10

- Plain lead sheath where no known corrosive conditions exist. In the case of existing lead cables in plant, located in areas where corrosion is manifest, an attempt is being made to place all cables under cathodic protection by the use of rectifiers or by using magnesium anodes.
  - Copper jacketed cable not used.
  - Tape and wire armored, thermoplastic and jute covered cables so far have presented no problems.
  - Polyethylene jacketed cables are used in all known corrosive areas.
- This company uses a copper half-cell as a reference ground electrode and feels that —0.70 to —0.90 volt or a change of 0.3 volt are within safe working limits.

11

- No specific rules.
- No specific limits are set forth. When a cable sheath is found to be positive to earth or to other substructures, except for short duration, remedial measures are taken.

12

- 2V potential to earth on plain lead.
  - None in use.
  - 85V to copper sulfate electrode.
  - None in use.
  - 2V potential to earth on jute.
  - Polyethylene jacketed cables used only as alpeth cable. Potential the same as bare lead.
- Between —.2 and —.5 volt cable-to-earth potential is the aim of our cathodic protection systems, regardless of the type of electrode used as a reference point.

13

- Cable sheath potentials with respect to earth, using a piece of lead sheathing for a test electrode.
  - c, d, e, f. Not generally used on the underground cable plant. Lead covered cables with Neoprene jackets over the sheaths are used. The sheaths of the jacketed cables

are bonded to the bare lead cable system and operate under the same sheath potentials.

2. We attempt to maintain the cable sheaths between 0.2 and 0.5 volt negative with respect to earth.

14

1. a. In general we install cathodic protection on our 138 kv and on some of the 34.5 kv lead cable sheaths and regulate the rectifier current to give an average negative potential between the lead sheath and a lead electrode of .2 to .3 volt. A copper sulfate electrode is also used at the same time and the readings from the two electrodes are plotted on the same chart with the lead cable sheath taken as the zero line. The average difference between the two electrodes is .585 volt. The copper sulfate electrode has been found to be the most stable.

b. None.

- c. One installation in sea water crossing the Los Angeles Harbor channel in which the steel armor is maintained about .85 volt to a copper sulfate electrode.

d, e, f. None.

2. For cathodic protection on our bare lead cable sheaths, we try to maintain an average of .2 volt with a minimum of .15 volt and a maximum of .4 volt referred to a lead electrode. Some peaking cannot be helped where the anode is close to the cable sheath being protected.

15

No Cathodic protection employed.

16

1. a thru f. 300 mv reduction in cable sheath potential, and/or reversal of current discharge from the cable sheath as determined by duct survey.

2. Reductions in cable sheath potential are limited to 500 mv wherever possible. Should the reduction in cable sheath potential be less than 300 mv, reversal of current discharge from the cable is used as the protective criterion.

17

1. a. Cable-to-earth potential minimum —.1 volt; maximum in alkaline soils —.75 volt measured to a lead half cell.

- b. Copper jacket —.1 volt to earth measured with a copper half cell.

- c, d, e, f. All of these cables have either a lead sheath over the case, aluminum and/or terne plate, or steel tape or wire, in some cases in combination with a plastic coating. A minimum of —.1 volt cable to earth (a lead sump electrode) is desired.

2. At the rectifier location, the cable should be at least —.5 volt to earth and at the far end of protection for a given station to a minimum of —.1 volt to earth.

18

1. a. Plain lead sheathed cable is considered under adequate protection if the potential, as measured to a lead electrode, is in a range between —.2v and —1.0v. Below —.2v the galvanic potential between sheath and electrode may constitute half of the reading, so that a .1v might more correctly be zero. Above —1.0v cathodic corrosion is possible in certain environments. An attenuation curve to show the degree of current pickup is helpful.

b. Not used.

- c. Tape and wire armored cable is used only for submarine crossings. No special treatment, considered as part of the lead sheathed cable extending from the crossing.

d. Not used.

- e. Used only in some older sections of aerial cable.

- f. Polyethylene jacketed cable is frequently used in known corrosive areas. Usually supplemented by some type of cathodic protection.

2. Covered in 1, a.

19

1. Referenced to a copper sulfate half cell: a. —.75 V; b. —.25 V; c. —.85 V; d. —.75 V; e. —.75 V; f. No data.

2. As above.

20

1. a. Sheath potential with respect to lead reference electrode must be cathodic.

b through f. None in operation.

2. Lead sheath cable potential desired is from —0.1 to —0.4 volt.

21

1. a. Lead ground plate or lead chloride half cells should be employed with plain lead cable sheath.

- b. We have no copper jacketed cables but we do have

copper tubes in underground ducts. Copper tubes may be tested with the copper sulfate half cell if they are in the ducts alone. If, however, copper tubes are in the same duct system and are cross bonded to the lead cables and the latter are preponderant, lead plate or the lead chloride half cell should be employed.

- c. We assume this means tape armored or wire armored cable, as we do not have cables armored with both tape and wire. Either armor over lead cables presents a rather complicated problem when placed underground, inasmuch as the jute on such cable when first placed in underground ducts acts to insulate between the lead and the soil, but as moisture lowers the earth resistance, a galvanic couple becomes a reality. The armor and lead should, therefore, be cross bonded at splices in order to reduce the galvanic potentials and the bonded cable should then be treated as a unit. After the first year the cable should be tested as though it were a lead cable but the negative potential applied should be approximately 0.2 to 0.34 volt instead of the usual nominal average potential of 0.12 volt which is considered the minimum average.

- d. Thermoplastic alone would require no protection.

- e. Jute alone would require no protection but the metal sheath under the jute, if a metal sheath is provided, should be tested and protected on the basis of the kind of metal employed in the sheath. The jute in itself would not be a factor unless the jute would be over a metal sheathing and no protective system was used.

- f. Polyethylene alone would need no protection. Polyethylene over a metal sheathing would require protective treatment for the kind of metal considered. Such a system would be provided primarily to prevent action against the metal sheathing in the exposed section of the man-holes or where imperfections or holes were present in the polyethylene jacket.

- g. The comments applying to f above would also apply to Neoprene over lead sheathing.

2. On lead sheath cables a minimum average potential to the surrounding soil should be negative 0.12 volt where the cable is alone and not surrounded by other metal underground structures, but where copper tubes are in the same duct lines or where iron pipe systems are in the soil adjacent to or paralleling the cable duct system, the negative potential to soil should be a minimum average negative 0.34 volt.

22

1. a. Change existing unsatisfactory potentials by 0.3 volt or maintain sheath throughout unsatisfactory area at a negative potential.

- b. None.

- c. Installations are not involved with cathodic protection systems.

- d. Used in lieu of cathodic protection.

- e. Same as c.

- f. Same as d.

2. Negative potential not to exceed 0.6 volt. System must not cause interference to other underground structures.

23

No installations.

24

1. a. .05V negative to earth using a lead coupon measuring electrode.

- b. Do not use.

- c. .05 negative to earth using a piece of the wire as a measuring electrode.

- d, e, f. Do not use.

2. .05 to .50 negative to earth.

25

1. Plain lead sheath, tape and wire armored, jute covered, polyethylene jacketed. Copper jacketed and Thermoplastic—not used by this company.

2. —.70 to —1.0V measured to copper sulfate half-cell where cathodic protection is applied.

## Section B—RECTIFIER GROUND BED DESIGN AND LOCATION

### Question B

Describe your method of ground bed design and installation.

# Company Number

1 We use steel rails in coke dust.

2 We have several so-called "all steel" station grounding networks, several of which are being equipped with cathodic protection using rectifiers and buried abandoned steel boiler tubes that would otherwise be sold as steel scrap. About a ton is buried in a trench about two feet deep. Tubes are laid end to end and butted together and welded together halfway around. Tubes are around 3½ inch OD. They are laid in the trench side by side. Then flat steel bars are used to cross-bond or tie all pipe runs together by welding. The number of runs varies, in higher resistance soils the runs are longest to maintain the lowest practical value of resistance while in low resistance soils the runs may be relatively shorter and still result in low resistance requiring minimum voltage from the rectifier. About a ton of steel is installed to obtain long life.

All joining welds and all other connecting facilities are thoroughly covered by Neoprene paint in order that the sacrificial action will not result in these connections opening due to wasting away of the metal.

All backfilling is done with the same material as removed when opening the trench.

These beds are located from 50 to 100 feet outside the area covered by the grounding system to be protected. At all but one station thus far checked, one bed only is satisfactory but at the one exception it was necessary to install a bed at two sides of the area. This occurred at the station having the lowest tested resistance for the grounding system.

3 The design depends on the available location, current requirements, etc. There are only two small beds on the cable system. These are old and made of scrap steel in a restricted area. On the gas system recent beds are made of up to 15 graphite anodes 3 x 60 inches and 15 feet apart if possible. Each anode in a 10-inch hole 12 feet deep with a special conducting backfill around the anode.

4 At present, we are using ground beds made up of five grounds usually 15 feet apart. Each ground is made by drilling a 10-inch hole in the earth nine feet deep. The anode is a 3 x 60-inch graphite rod entirely surrounded by breeze coke. A single No. 6 Neoprene covered wire is run from each anode to the nearest pole for test purposes. Where the current exceeds four amperes per anode, additional grounds will be provided.

5 Our ground bed is an old abandoned gas main of steel pipe. We expect that this will last about five years. The main is in a fairly good location with respect to the cables we are interested in protecting. It is recognized that we may have to use magnesium anodes for some of the more remote sections of cable. As indicated above, we are still testing the effectiveness of the installation.

6 We do not have a standardized design of ground bed on the lead sheath cable system. We have three installations of scrap cable in vacant duct supplied by a rectifier voltage of 2 to 4 volts and one installation of buried steel scrap rails buried near the duct bank with rectifier voltage of similar magnitude. All designs of ground beds are based on corrosion engineering experience. The cathodic protection current is adjusted after installation so as to result in satisfactory conditions as indicated by test.

7 Our ground bed design is controlled by permissible ground bed resistance and the total current to be dissipated. In our one important ground bed installation we used five graphite ground rods, suitably backfilled, to get the desired low initial resistance of .65 ohms. This is two rods more than were actually required to carry the current based on one ampere per square foot of rod surface.

8 No set of rules is furnished by this company for ground bed design and locations. All new ground beds employ graphite or carbon anodes and graphite backfill. We are guided by the rules furnished by the manufacturer of the anodes. All our ground beds are now of the point type, however we are considering the use of distributed ground beds in some locations.

Our company submits plans for proposed ground bed in-

stallations to the Detroit Committee on Electrolysis. The committee arranges for joint tests with all companies or utilities whose underground plant may be exposed to corrosion due to the proposed installation.

9 No ground bed installations. Return of rectifiers to negative buss or pipe systems.

10 There is no ground bed in use at the moment. However, we currently are engineering a job to utilize a section of abandoned trolley rails, which parallel a cable run in downtown Norfolk, as a ground bed to dissipate approximately 150 amperes. A carbon rod ground bed using twelve 3 x 60-inch graphite anodes is also in the engineering stage. This installation is expected to handle 100 amperes.

11 Rectifiers used only in vicinity of two power plants, mainly for underground pipe protection, but lead sheath protection is provided. Point type ground beds used. Each installation individually engineered.

12 Our recent ground beds are installed using carbon anodes and a BF-3 backfill following manufacturers' suggestions as to the depth and location from the cable runs.

Previous installations have been 10-foot rail sections buried in coke breeze located at various distances from cable runs. However, none were closer than 500 feet.

13 Each ground bed installation is designed to correct conditions at a specific location. Test data usually determine the type of installation to be made.

14 Our anode consists of a 100-foot-long, 135-pound used rail road rail buried six feet deep and encased in a backfill two feet square around the rail consisting of a mixture of soil and approximately 5 pounds of salt (sodium chloride) per cubic foot mixed in a cement mixer and poured in like cement. After this has hardened, we place a 6-inch layer of medium size rock on top and then the balance of the trench is backfilled with the original earth removed during excavation.

Standpipes made from 4-inch concrete duct, perforated near the bottom, extend from the rail to the surface of the ground for future watering of the anode bed.

The anode lead is connected to the 100-foot rail at twelve places by means of twelve cups which are filled with ozite compound to protect the connection from the action of the anodic current leaving the iron rail.

In two installations we used coke breeze in place of the salt soil mixture.

The anode is placed as far away from the cable line as practicable, usually about one or two city blocks.

15 Have no rectifier ground beds.

16 All rectifier installations made to date utilize a piece of scrap cable, equal in length to the protected cable section, for a ground bed. The scrap cable is installed in the lowest spare duct and sectionalized as required to achieve the desired current distribution. Current requirements are established by use of a motor-generator set, adjusting the output until the desired potential conditions are obtained. Individual wire connections are provided from the positive terminal of the rectifier to the sections of the ground bed and current flow to each is controlled by resistors. If current requirements are large, more than one rectifier may be required.

17 Copies of drawings submitted indicate in detail our procedure.

18 The location of the ground bed is determined by interference hazard, available right of way, power source and attenuation obtained on line to be protected.

An earth resistance survey is made in the selected area and driven ground rods are installed for a temporary test anode. The anode material used is scrap track, cast iron pipe, H beams, carbon and graphite rods. All of these materials are surrounded by coke breeze to lower the earth contact resistance and extend the anode life.

19 Selection is made depending upon available sites, earth resistivity, trial bed resistance, convenience of construction, available power supply.

20 Ground bed installations normally consist of an anode pulled



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into an empty duct of a conduit run. The quantity and type of material are determined by the magnitude of the protective current required.

**21**  
The best ground bed is one that requires no maintenance over long periods of use. The grounds can be made by driving iron pipe into the soil or through the use of steel rails 10 to 20 feet in length. If space is not limited, a 20-foot length of old rail may be buried horizontally in the soil with the electrode surrounded by about three-fourths to one ton of fine carbon or coke breeze. The rail should be buried to a depth depending upon the type and resistance of the soil but, in general, a depth of 2 to 3 feet will be satisfactory. The nearest part of the ground bed should preferably be not closer than 10 to 15 feet to the cable system being protected. If space for the ground bed is limited, two 10-foot sections of rail surrounded by coke may be employed.

Pipe grounds of iron pipe  $\frac{1}{4}$  to 2 inches in diameter may be used and driven into the soil to a depth of 8 to 10 feet and spaced 10 feet between the driven grounds. Deeply driven pipes or rods are excellent for reducing the resistance of a ground, but such grounds are not preferable for long life current carrying grounds. Galvanized pipe will provide excellent grounds when new, but as the zinc coating is dissipated, a coating of incrustation is often formed on current carrying grounds which increases the effective resistance and thus reduces the current carrying capacity of the ground bed. Zinc coated pipe should, therefore, be avoided except possibly when used in very low resistance soils.

**22**  
Abandoned trolley rails, buried manhole covers, buried railroad rails, buried graphite rods, vertical pipe anodes, duct anodes. All but the last are point anodes.

**23**  
No installations.

**24**  
Do not use.

**25**  
Have not done enough of this type of work to establish a specific design.

## Section C—INSULATING JOINTS

### Question C

Are insulating joints used in any manner in connection with cathodic protection (either rectifier or galvanic anode) for control of the protective current?

#### Company Number

1 No.

2 No.

3

Insulating joints or features are used in connection with cathodic protection on pipe lines and pipes of Oliostatic cables but not on lead covered cables.

4

Insulating joints are generally used at building entrances to avoid incidental connections to the water pipe system. They are also used occasionally to sectionalize a cable run.

5 No.

6 No.

7

Insulating joints are used to isolate the sections under cathodic protection.

8

Insulating joints are used at building cable entrances to separate telephone cable plant from pipe structures in stray current areas. They are used also in non-stray current areas on a case basis to isolate aerial from underground cable plant. In general we do not recommend the use of insulating joints except where they are specifically required for corrosion protection reasons.

9 Yes, in certain cases.

10

Insulating joints are used extensively in our underground plant to isolate the cables. In most cases we have found it very effective.

11 No.

**12**  
Insulating joints have been used to isolate underground dips in aerial cables so that magnesium anodes would be more effective in protecting the dip.

**13** No.

**14**

Our principal use of insulating joints is on communication or control cables which are installed in the same duct bank with high voltage cables that are under cathodic protection. The insulating joint is placed in the first manhole or pull box after it leaves the main conduit line.

**15** No.

**16** No.

**17**

The question is not clear to me as to whether it is intended to discuss the use of insulating joints to break up the cable line or to use the joints to isolate the cable plant from other metallic substructures or buildings. The only cases in which insulating joints are used to break up the cable route is when the cable that is being protected transverses a steel or reinforced concrete bridge. Then, of course, joints are placed on each side of the bridge and an insulated copper wire is also placed to conduct current past the insulated section. Insulating joints are used extensively in laterals to buildings in order to isolate the cable from other metallic substructures. Within the next 6 or 8 months all central offices will have insulating joints in the cable vaults.

**18**

Insulating joints are used frequently to eliminate the copper-lead couple of station grounding. They are also used to clear the sheaths from the neutral system and thus obtain isolation from water and gas mains. In both of these arrangements cathodic protection is usually involved.

**19**

We have none at present, but would not hesitate to use if indicated.

**20** Not used.

**21**

Insulating joints are always a possible source of trouble and their number should be kept to a minimum. On the other hand, their intelligent application increases the safety afforded to the plant and lowers the operating and maintenance costs of the protective system.

**22**

Used to isolate protected plant from foreign underground structures.

Used to isolate aerial cable sheath when that sheath is used as a current distribution medium.

**23** No.

**24** No.

**25**

Yes. Generally limited to situations involving a limited number of cables where the currents and potentials involved are quite low.

## Section D—PROTECTIVE COATINGS

### Question D

1. Are protective coatings used in any manner to reduce the size of the cathodic protection installation (rectifier or galvanic anode)?

2. Have you experienced any detrimental effects of cathodic protection currents on your protective coatings?

#### Company Number

1 1 and 2, no.

2

1. In station grounding systems some water pipes are wrapped to reduce the amount of current that must be handled by the rectifier.

2. No.

3

1. Protective coatings are used but not to reduce the size of the rectifier or anode. The cathodic protection is used to cover where coatings are faulty or otherwise inadequate.

2. Detrimental effects of cathodic protection currents on protective coatings have not been experienced to this time.

- 4 No.  
5 No.  
6  
1. As stated above, we are now buying our cable with a Neoprene jacket in order to eliminate the effect of galvanic action.  
2. No detrimental effects so far.  
7 1 No. 2. None on cable sheath coatings.  
8 1 and 2, no.  
9  
1. We do not use protective coatings to reduce the size of cathodic protection installations.  
2. We have no experience with cathodic protection currents on protective coatings. We have no experience with cathodic protection currents adversely affecting aliphath sheath cable.  
10  
1. Infrequently. Polyethylene jacketed and corrosion protected cables or asphalt and pitch impregnated tape.  
2. None observed.  
11  
1. No protective coatings have been used in this area and it is not contemplated that any will be used.  
12 1 and 2, no.  
13  
1. Protective coatings have not been used to reduce the size of a cathodic protection system, but they have been used to reduce the current flow from short sections of cables replacing corroded cables until some form of cathodic protection can be applied.  
On exchange cables in areas of severe corrosion aliphath cables have been specified.  
At the present time all buried intercity and exchange cables are jute protected.  
14 1 and 2, no.  
15 1 and 2, no.  
16 None used.  
17  
1. It is not considered desirable to disturb cables which are in place to effect installation of a protective coating. Some recently installed cables have been Neoprene-jacketed prior to installation, but cathodic protection of these has not yet been required.  
2. No coated lead-sheathed cables under cathodic protection.  
18  
1. In existing bare lead sheathed cable runs under cathodic protection, we specify that additional cables being placed in the run have some type of protective covering which in turn will reduce the total current requirement for the run being protected.

For all tool or trunk cables, protective coatings are being requested.

2. No. Perhaps we should not say yes or no as the cathodic protection has been in service on these cables but four years.

## 19

1. Although not common in the past, protective coatings are now being used with the view of providing cathodic protection at a reasonable value of current. At present the more frequent use is where magnesium ribbon in a spare duct will provide a limited amount of current.  
2. No. We do not expect to have any trouble from blistering, if the protection is maintained at a low value.

20 1 and 2, no.

## 21

1. Neoprene jackets are used as protective coatings in severe corrosion areas. The use of a fairly heavy pulling grease with good self-healing properties is now standard practice when pulling lead sheath cable into conduit. This grease tends to act as a protective coating. If the cable is completely jacketed, no cathodic potentials are applied.  
2. No detrimental effects have been detected from cathodic protection currents on protective coatings.

## 22

1. We have employed Neoprene jacket over lead sheathing in situations where the oil was very low in resistance, where chloride or organic acids were present or where the cable was inundated most of the time. The above would be true regardless of whether a rectifier or magnesium or zinc anodes were employed.  
2. We maintain a minimum average protective potential which is never injurious. It is only where high negative potentials are employed that difficulty will be encountered.

## 23

1. Protective coatings have not been used to reduce the size of cathodic protection installations.  
2. No detrimental effects from cathodic protection currents have been experienced on protective coatings.

24, 25 and 26, 1 and 2, no.

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## TECHNICAL COMMITTEE ACTIVITIES

# High Silicon Anode Data Are Digested in Report

## 24 Committees Are Scheduled to Meet In San Antonio

Twenty-four technical committees will hold meetings during the South Central Region meeting scheduled October 23-26 at the Gunter Hotel, San Antonio, Texas. Although October 23 and 24 have been reserved for technical committee meetings, so many requests for meetings have been made some are being scheduled on the 25 and 26 to avoid serious conflicts of interest.

Committees scheduled to meet are:

- T-1 Corrosion in Oil and Gas Well Equipment: Full day meeting
- T-1B Condensate Well Corrosion: Half day meeting
- T-1D Sour Oil Well Corrosion: Half day meeting
- T-1F Metallurgy: Half day meeting
- T-1G Sulfide Stress Corrosion Cracking: Half day meeting
- T-1H Oil String Casing Corrosion: Half day meeting
- T-1J Oil Field Structural Plastics: Half day meeting
- T-1K Inhibitors for Oil and Gas Wells: Half day meeting
- T-1M Corrosion of Oil and Gas Well Producing Equipment in Offshore Installations: Half day meeting
- T-2C Minimum Current Requirements for Cathodic Protection: Half day meeting
- T-2D Standardization of Procedures for Measuring Pipe Coating Leakage Conductance: Half day meeting
- T-2E Internal Corrosion of Product Pipe Lines and Tanks: Half day meeting
- T-2K Prefabricated Plastic Film for Pipe Line Coating: Half day meeting
- T-3A Corrosion Inhibitors: Half day meeting\*
- T-3G Cathodic Protection
- T-5B-2 Sulfide Corrosion at High Temperatures and Pressures in the Petroleum Industry: Two half day meetings
- T-5C-1 Corrosion by Cooling Waters (South Central Region): Half day meeting
- T-5D Plastic Materials of Construction: Half day meeting
- T-5E Stress Corrosion Cracking of Austenitic Stainless Steels: Half day meeting
- T-6A Organic Coatings and Linings for Resistance to Chemical Corrosion: Half day meeting\*
- T-6B Protective Coatings for Resistance to Atmospheric Corrosion: Half day meeting
- T-6E Protective Coatings in Petroleum Production: Half day meeting
- T-6D Industrial Maintenance Painting in the Process Industries: Half day meeting
- T-7D South Central Region Corrosion Coordinating Committee: Half day meeting

\* Tentative.

### COMMITTEES INVITED TO THESE MEETINGS

Northeast Region: October 15-17, 1956, Drake Hotel, Philadelphia, October 15 reserved for technical committee meetings. To reserve meeting space notify T. J. Hull, NACE, 1061 M & M Bldg., Houston.

South Central Region: October 23-26, 1956, Gunter Hotel, San Antonio, Texas. October 23-24 reserved for technical committee meetings. To reserve meeting space notify T. J. Hull, NACE, 1061 M & M Bldg., Houston.

North Central Region: November 15-16, 1956, Detroit. To reserve meeting space notify T. J. Hull, NACE, 1061 M & M Bldg., Houston.

## Corrosion Products Unit Surveys Activity Topics

A questionnaire covering possible topics for future committee activity has been circulated to members of Technical Unit Committee T-3B on Corrosion Products. Subjects suggested for T-3B activity include

1. Diagnosis of corrosion problems through identity and properties of corrosion products.
2. General references to publications, surveys, reports, data, etc.
3. Fouling of heat transfer surfaces. Plugging lines, valves, etc., by corrosion product deposition.
4. Classification of corrosion reactions which produce corrosion products of definite composition.
5. Thin films; soluble versus insoluble products.
6. Chemical composition of corrosion products. Analytical routines for the various metals.
7. Variables involved in formation and equilibrium of corrosion products.
8. Removal of corrosion products from equipment or media.
9. The role of corrosion products in accelerating corrosion rates.

Future work of T-3B will probably be guided by results of this questionnaire. To date most of the work of T-3B has been towards compilation of a bibliography of corrosion products. It is anticipated the bibliography will be completed in the near future.

Unit Committee T-3B is represented on the ASTM Joint Committee on Chemical Analysis by X-ray Diffraction. During 1955 four compounds were submitted for the ASTM card index of x-ray diffraction data, iron sulphite, ferrous bicarbonate and two copper chloride hydrates.

A. H. Roebuck, Continental Oil Company, Ponca City, Oklahoma and D. A. Vaughan, Battelle Memorial Institute, Columbus, Ohio are chairman and vice-chairman respectively of Unit Committee T-3B.

## Clear Trends Are Shown in Replies To Questionnaire

Clear trends on the most important points related to the use of high silicon anodes in cathodic protection installations are defined in reports received by Task Group T-2B-4 of Unit Committee T-2B on Anodes for Impressed Currents. The reports were developed from replies of more than 75 percent of 100-odd questionnaires to companies having the anodes in service. Many users were not queried because detailed data on their installations were available to the committee already.

A minimum of conflicting data on the three areas of inquiry, ground beds, fresh water and sea water were found in the replies. Many of the 35 files of information compiled by the task group cover more than one installation.

### Results of Backfill

It was the consensus that no electrical difference exists between a ground bed including a graphite anode and one including one of high silicon iron. Numerous installations of cast iron anodes in tamped coke breeze substantiated the contention that the ground rod serves merely as an electrical contact in the backfill-anode.

Anode resistance and current discharge from graphite and cast iron were of the same magnitude and many cases were cited where either cast iron rod additions were made to existing graphite rod ground beds or new beds were installed using both materials. In most instances the 1½ or 2-inch diameter by 60-inch sizes provided the same results.

The task group concludes that the single anode resistance of a high silicon iron anode in a 10-foot column of backfill one foot in diameter is given by the expression  $R = 0.002 \epsilon$  where  $\epsilon$  is the resistance of the earth in ohm-centimeters.

All laboratory and field tests indicate that coke breeze, wet or dry, has no bad effect on high silicon cast iron. In well-tamped coke breeze consumption rates on high silicon are sufficiently low to indicate 20 years' service or more.

### Some Backfills Unsatisfactory

Because unsatisfactory results were reported with two backfill materials other than coke breeze the task group does not recommend materials other than coke breeze now. When gypsum was tried it did not lower anode resistance sufficiently and a wood fiber-plaster backfill reacted similarly. Further investigation of this point is planned.

Tests on these mixtures and others will be made in the laboratory.

The report says it is clear that while high silicon is not immune to attack, because of the concentrated mass with a metal anode of this type it is possible

(Continued on Page 82)



## Cooling Water Group Elects Dillon and Brooke

C. P. Dillon, Carbide and Carbon Chemicals Co., Texas City and M. Brooke, Phillips Petroleum Co., Old Ocean were elected president and vice-president respectively of NACE Task Group T-5C-1 on Corrosion by Cooling Waters, South Central Region. W. W. Wheeler, Rohm & Haas Co., Houston also was elected secretary at the meeting of the committee at Ben Milam Hotel, Houston May 16.

The recirculating cooling water subcommittee of T-5C-1 presented a report on a questionnaire that had been circulated. Mr. Brooke, chairman of the recirculating cooling water subcommittee was instructed to continue the committee work to set down recommended treat-

ments for various cooling waters through the exchange of information and experience.

It is expected that the T-5C-1 test program on stress cracking of stainless steel will be started this summer. The committee has decided that if desired corrosion coupons can be obtained, Erickson impression coupon types of stress specimens will be tested simultaneously with tensile specimens.

The committee discussed use of aluminum as a material of construction in cooling water. It was developed that there is little information on this subject. The committee is considering sending a questionnaire to get data on the use of aluminum.

## Four Committees Plan Sessions at Detroit

Four technical committees have scheduled meetings during the Northeast Region Fall Meeting. The meeting will be held at the Drake Hotel, Philadelphia, October 15-17. October 15 has been reserved for technical committee meetings.

Committees scheduled to meet are:  
T-2K Prefabricated Plastic Film for Pipe Line Coating  
T-4F Materials Selection for Corrosion Mitigation in the Utility Industry  
T-4F-1 Materials Selection in the Water Industry  
T-7A North East Region Corrosion Coordinating Committee

Three additional committees have expressed interest in holding meetings but have not made definite commitments. Meeting schedules will appear in the August and September issue of CORROSION.

## High Silicon Anode—

(Continued From Page 81)

to predict its life even under the most severe conditions.

So far high silicon iron has been used successfully in fresh water. Because other materials have limitations in this medium it is possible to determine the relative merits of silicon iron quicker.

### pH Range Not Critical

Laboratory tests in fresh water show that high silicon irons corrode at a rate of 0.25 pounds per ampere year in the 0.3 ampere per square foot range. This rate appears to be independent of pH because there was no marked difference in waters ranging in pH from 3 to 10.

Two year service results correlate well with laboratory results and indicate that life expectancy of high silicon iron is excellent under all conditions tested. None of the data collected covering over 50 installations indicate the material is not suitable.

### Trials in Sea Water

Numerous trials of high silicon iron in sea water at a wide range of current densities have been under way. Results indicate the most suitable density to use depends wholly on the life expectancy of the installation. If a relatively large anode is used at a current density of less than 3 amperes per square foot, a 10-year expectancy seems definite. Increased current density shortens and reduced density lengthens life.

What effect heavy silt will have has not been fully ascertained. When anodes are allowed to sink freely it is preferred they be supported by ropes. If the silt permits dissipation of the chlorine created no difficulty will result, but if the silt holds the chlorine, increased anode consumption occurs. Many installations have been made successfully by taking these requirements into account.

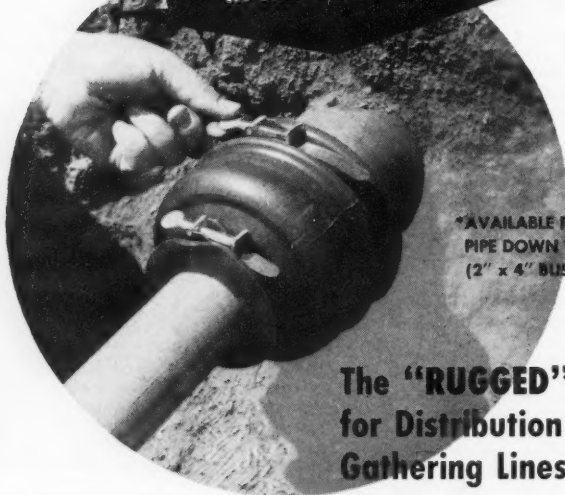
### Molybdenum Is Helpful

Molybdenum alloyed with the silicon iron appears to reduce the trouble experience with chlorine. The effect of alloying with this metal also is being studied on anodes used in severe environments.

Laboratory tests of the molybdenum-silicon iron alloy have shown it to have superior characteristics especially at higher temperatures. Failure of high silicon anodes in service at 175 to 200 F prompted the evaluation of the molybdenum alloy, now under tests to determine its uses under severe conditions.

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## T-4B-3 Finds Lead-Lead Chloride Half Cells Are Satisfactory for Working Electrodes

Freshly made lead/lead-chloride half-cells with a lead chloride-potassium chloride electrolyte will give satisfactory performance as a working electrode, according to the results of tests made by Work Group T-4B-3A on Half-Cells. This work group is under NACE Task Group T-4B-3 on Tests and Surveys.

In a group of 14 lead/lead-chloride electrodes having lead chloride-potassium chloride electrolytes the range in values was found to be 4.8 millivolts with an average of  $-0.5674$  volt to a saturated calomel electrode. These results were obtained with freshly prepared electrodes and do not include drifts in potential with time. The temperature coefficient of these cells appeared to be negligible.

The work group examined difficulties that had been reported by various workers in getting reproducibility and in preparing the electrolyte for a lead/lead-chloride half-cell. Solubilities of lead-chloride, copper sulfate and potassium chloride were plotted as a function of temperature. The addition of potassium chloride to a saturated lead chloride electrolyte to increase conductivity reduces the lead ion concentration due to the common ion effect and produces changes in the electrode potential. This indicates a difference of about 140 millivolts in electrode potential between a saturated lead chloride electrolyte and one containing an addition of 400 grams per liter of potassium chloride. It demonstrates one of the reasons for lack for

reproducibility if the electrolyte of the lead/lead-chloride half-cell is not controlled.

The work group report also stated that the copper/copper-sulfate electrode has certain objectionable features which make it unsatisfactory under some conditions. In duct surveys, for example, leakage of copper sulfate is a serious hazard. The hazard is created by metallic copper which will be deposited upon the lead sheath surface from the sulfate solution and will form local dissimilar metal galvanic couples. Where an agar gel salt bridge is desired, the copper sulfate will destroy the gel and permit contamination or loss of copper sulfate solution. Under such conditions the lead/lead-chloride electrode could be used.

Reproducibility of field type copper/copper-sulfate electrodes was revealed in the results of 93 measurements on a group of 31 half-cells. The mean value of the potential to a saturated calomel electrode was  $+0.070$  volt. The range was 17 millivolts. In connection with this study, the temperature coefficient of a copper sulfate electrode was found to be about 0.6 millivolts per degree F when the other half of the cell was two copper sulfate half cells connected with a salt bridge. However, when the temperature of a cell comprised of lead sheath/soil/copper sulfate/copper was varied over a considerable range, the temperature coefficient was found to be negligible. The report added that if any

temperature correction is applied it should be based upon the difference between the cable sheath temperature and the temperature of the half-cell.

A member of the task group asked about the use of copper sulfate half-cells in the field. The half-cells can be contaminated if left in sea or brackish water over a considerable length of time. If contamination is suspected, the half-cell should be checked with a simple cell containing copper sulfate solution and a copper wire for reading variations.

## Wetting and Drying in Salt Solutions More Severe Than Steady Exposure

Corrosion of steel exposed to the atmosphere depends upon numerous factors including alternate wetting and drying of salts on metal surfaces. The latter is more serious than continuous contact with brine, a member of Technical Unit Committee T-4D on Corrosion by De-icing Salts said at the committee's meeting at New York last March.

This member added that steel exposed to the atmosphere ordinarily develops a protective film of rust, because of the excess of oxygen and the drying action of the sun, reducing the corrosion rate after a time because of the adherent rust film.

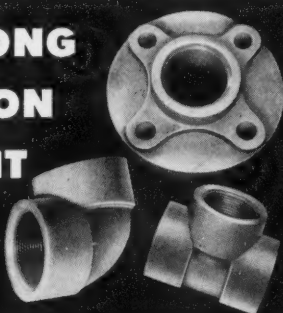
A panel of stainless steel mounted at an angle on the roof of a building in New York showed no corrosion on the upper face exposed to the sun and rain but showed rusting over much of the underside, it was pointed out. It was noted that corrosion is more serious on surfaces shielded from the sun and denied the cleansing action of rain. The alternate immersion test using de-icing salt solutions in the laboratory does not reproduce field conditions where brines are splashed on the under side of car fenders and on evaporating leave salt incrustations on the metal. If these are not washed off moisture is retained, even in atmospheres far from saturated with moisture. The conclusion was that when de-icing salts or sea water spray is present a rust film does not protect and corrosion continues at a rapid rate.

Another member said experience indicates concentrated sodium chloride solutions are not as corrosive as dilute solutions and under high humidity the deliquescence of the particular chloride salt may be a factor. Other members noted that their laboratory tests confirmed the conclusion that when the de-icing salts or sea water spray is present a rust film does not protect. One member remarked that a similar observation had been made in gasoline tankers ballasted or washed with water. Empty tanks under varying humidity conditions corroded faster than ballasted tanks.

One company has tried undercoating type materials for maintenance painting buildings exposed to chlorides and the weather. These proved to be of no value unless the metal surface was properly prepared and primed with corrosion inhibiting primers. Another member felt that undercoating of vehicles provides good corrosion protection if the coatings are non-porous. Presently used undercoatings are selected initially for sound deadening qualities rather than corrosion protection. It was reported that one large truck and coach manufacturer uses

(Continued on Page 86)

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## Maintenance Painting Unit Will Organize At Regional Meeting

The organizational meeting of NACE Technical Unit Committee T-6D on Industrial Maintenance Painting in the Process Industries will be held during the South Central Region Meeting scheduled in San Antonio, Texas, October 23-26.

J. C. Coffin, The Dow Chemical Co., Midland, Michigan plans to formally organize the committee, make task group assignments and outline objectives for committee work. Scope of the new committee is to discuss, study, report and publish information relative to industrial maintenance painting and to advance the cause of corrosion engineering by informing process industry management and supervisory personnel of the advantages to be gained by sound corrosion control and prevention practices. Emphasis will be placed on protective coatings applications and painting programs.

Mr. Coffin invites all NACE members interested to attend the meeting.

## Three Coordinating Units Will Meet This Fall

Three unit committees of Group T-7, Corrosion Coordinating Committee will hold organizational meetings at NACE regional meetings this fall.

T-7A, Northeast Region Corrosion Coordinating Committee will hold its organizational meeting October 15 during the Northeast Regional Fall Meeting in Philadelphia. C. A. Erickson, The Peoples Natural Gas Co., Pittsburgh, Pa. chairman of the T-7A plans to begin organization immediately although the October 15 session will be the first formal gathering.

Jack M. Fouts, New York Telephone Co., Buffalo, N. Y., chairman of T-7 plans to hold an organizational meeting of T-7B North Central Region Coordinating Committee at the North Central Region Meeting in Detroit November 15. Mr. Fouts has not announced the names of officers but expects they will be chosen before or at the meeting in Detroit.

T-7D South Central Region Corrosion Coordinating Committee will hold an organizational meeting at the South Central Region Meeting in San Antonio, Texas October 23-26. Mr. Fouts reports officers of T-7D have been selected but that official appointments have not been completed.

## Wetting and Drying—

(Continued From Page 84)

an undercoating material containing a chromate-type inhibitor or pigment.

The committee discussed the relative merits of laboratory type corrosion tests for de-icing salts and inhibitors versus field tests and agreed that answers on de-icing salt corrosion cannot be found by laboratory type tests. Task forces of the committee were asked to work on the subject.

Technical articles published in Corrosion come from many foreign countries including Egypt, Germany, Australia, New Zealand, Israel, France, Belgium and Japan.

# how to CUT CORROSION LOSSES

a report by Koppers Company, Inc.



Russell C. Stromquist  
Corrosion Consultant

Recently, we were asked to recommend protective coatings in a plant on the West Coast. In analyzing their coating and enamel needs, we did our usual survey of the installation. After the survey, the customer's Chief Engineer remarked, "You fellows certainly go to a lot of trouble just to tell us what coating system we should use."

We do—because we know it is good for our customers and, therefore, good for us. Case history records prove clearly that careful study *before* making recommendations insures a better protective coating job at

lower annual cost. In analyzing protective coating needs, our corrosion engineers follow a "pre-coating check list" based on experience on thousands of jobs.

\* \* \*

The first step in the pre-application survey is a study of the environment. Specifically, you should always take into account the corrosive atmosphere: such factors as acid fumes, intense sunlight, salt air, etc. Physical environment—exposure to abrasion or impact—also plays an important part in the selection of an effective coating system.

The extent of temperature variation and expected minimum-maximum temperatures are important considerations, since the coating chosen must (a) resist low-temperature embrittlement, (b) resist high-temperature flow and (c) harden properly at service temperature.

The moisture environment too, is important in selecting protective coatings. Besides necessary water resistance, the coating should stand-up under pronounced wet-dry cycles.

A thorough cost analysis is a vital part of any pre-coating survey. Many factors are involved, varying in importance with the specific application. For example, total coating cost—made up of surface preparation and application costs—must be balanced against the cost of periodic maintenance. In some cases, the coated surfaces will not be accessible and coating-life will be a *direct* measure of the life of the material.

The cost of probable shut-down or loss of production time is perhaps one of the most important evaluations that must be made in intelligent selection of corrosion-preventing coating systems. Often, it outweighs the direct replacement costs of materials to be protected.

\* \* \*

This pre-coating check list, detailing the protection required and under what circumstances, is a key factor in the exceptional performance of Koppers Bitumastic® coatings. Such thoroughness sometimes leads us to willingly recommend some material other than one of Koppers eleven basic Bitumastic coatings to solve a customer's problems.

\* \* \*

In the next report, we will discuss why surface preparation is so vital to the life and economy of any protective coating. Meanwhile, we'd like to hear about your corrosion problems. Koppers Company, Inc., 1300 Koppers Bldg., Dept. 100G, Pittsburgh 19, Pa. District Offices: Boston, Chicago, Los Angeles, New York, Pittsburgh and Woodward, Ala.



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## Platinum Anodes More Economical Than Alloy Platinum-Palladium, Task Group Concludes

The use of platinum and palladium anodes for cathodic protection systems on the hulls of ships operating in salt water was considered by Unit Committee T-2B's Task Group T-2B-5 on Use of Platinum and Palladium, etc. for Anodes at the NACE New York Conference. Laboratory tests were made using  $1\frac{3}{16}$  by  $3\frac{7}{8}$  inch samples of platinum and palladium alloys in polarization test apparatus. Lowest corrosion rate was recorded for a 90 platinum—10 palladium anode. Slight increases were found in the corrosion rate as the amount of platinum was reduced. Palladium's corrosion rate increased moderately until a 50-50 alloy was reached when the rate increased markedly. Pure palladium has a high corrosion rate.

The group's report indicates there seems to be no point in using a platinum-palladium alloy because pure platinum is just as economical. A 60 palladium-40 silver alloy was found to be unsuitable also.

### Platinum Anodes Discussed

One member of the committee discussed his experience with platinum anodes. Some of the principal points were:

1. A penetration rate of 5 mils in 20 years at current discharge of 60 amperes per square foot is contemplated.

2. Materials used on anode supports must be resistant to the oxy-chloride produced in the vicinity of the anode.

Polyester resins have been found suitable coatings.

3. Cold bonded Neoprene coatings have given some trouble in the vicinity of platinum anodes. They tended to be lifted by chemical reactions.

4. Thickness of platinum clad must be uniform and without holidays which would permit discharge of current from base metal.

5. Platinum clad on coin silver anodes 48 inches long had a resistance of 0.4 ohm at a current discharge of 2.5 amperes per volt impressed.

6. Lucite insulation has been used successfully with platinum anodes.

7. Platinum clad anodes cost approximately \$100 a foot.

### Foil Anodes Considered

A new type of anode for use on ship hulls consisting of a foil of 80 platinum-20 palladium was discussed by T-2B. The foil is used in a 7-inch diameter disk contained in a holder having a diameter of 10 inches which projects about  $\frac{3}{4}$ -inch from the hull. Up to 15 volts can be impressed on these anodes and approximately one ampere current discharge per volt impressed is possible.

Approximately 5000 square feet of hull surface (using a 4-foot radius shielding blanket around each anode) can be protected by one anode. On one ship with about 125,000 square feet of hull surface about 24 anodes were used.

Automatic current controllers were connected to the electrodes to regulate current output to about 850 mv.

A polyester holder with a protective grid is used to hold the foil anode. Connection to the ship interior is by a gland through the hull. Approximate material cost of one anode, with glands is about \$550. A typical stern installation, including controllers, costs about \$3300 with an additional \$1000 for installation. A ship in yard can have such a system installed in 24 hours.

## Deep Ground Beds Weighed For Use in Congested Areas

Results of installing deep vertical ground beds, some with anodes placed as much as 425 feet below the surface were discussed at a meeting of T-2B in New York during the March NACE Conference. One installation was described at a navy yard using 20 ground beds each consisting of a 10-inch casing bored vertically to 80 feet and containing up to nine 4 by 80-inch graphite anodes backfilled with coke breeze.

Another committee member described four years' experience with a steel-rail ground bed placed 300 feet deep with the anodes in low resistivity clay at that depth.

These ground beds were constructed with the aim of duplicating the effect of remote beds in congested areas. At 10 amperes output, this member said, there was no detectable potential gradient at the surface over the ground bed location.

Another member told of a graphite ground bed installed 425 feet deep in an abandoned well in a congested plant area. Good current distribution was reported.

Other reports included:

1. Deep ground beds installed in filled

ground having ground water about half sea and half fresh water operate satisfactorily with good current distribution.

2. Apparent gas blocking was reported in a 75-foot deep bed consisting of ten anodes consisting of a 5-inch by 8-foot rod backfilled with earth. Resistance increased markedly. Initial output was 40 amperes at 12 volts but after three weeks, output was 17 amperes at 40 volts.

After a one and one-half day shut down output was at the original value, but decreased with time.

More graphite rod anodes backfilled with coke breeze 18 inches below and 36 inches above, with crushed rock to the surface were installed. This installation showed no resistance increase during operation.

Task Group T-2B-2 on Ground Beds Construction is preparing a questionnaire designed to gain further information for a report to T-2B.

## Effect of Bacteria on Non-Ferrous Metals Needs Investigation, Group Says

Bacteria do influence the rate of corrosion but more research is required before probable mechanisms can be fully understood. This is the conclusion of the project committee T-4B-1D appointed to investigate and develop technical information on corrosion by microbiological action given in a report to Task Group T-4B-1 on Lead and Other Metallic Sheaths at the task group's March meeting in New York.

The report briefly summarized information presently available on the microbiological corrosion of metal stating that most investigations pertained to iron and steel. However, bacteria may cause corrosion of metals other than iron and it is known that zinc, aluminum, lead, tin and other metals corrode under anaerobic conditions.

Task Group T-4B-1 has terminated project group T-4B-1A on Concentration Cells. The project group completed its assignment and reported the result in project group report "Cell Corrosion on Lead Cable Sheaths" which was published in the May, 1956 issue of CORROSION. V. B. Pike, Bell Telephone Laboratories, Murray Hill, N. J., chairman of the project group was thanked by the committee for preparation of the report.

Project Group T-4B-1E, assigned to prepare a descriptive list of failure classifications to be used as a guide in reporting cable sheath failures has been asked to assimilate data available and to prepare a report giving a recommended list of failure classifications which can be submitted for publication.

Valuable information on new developments of commercial importance may be found in the New Products Section of Corrosion.

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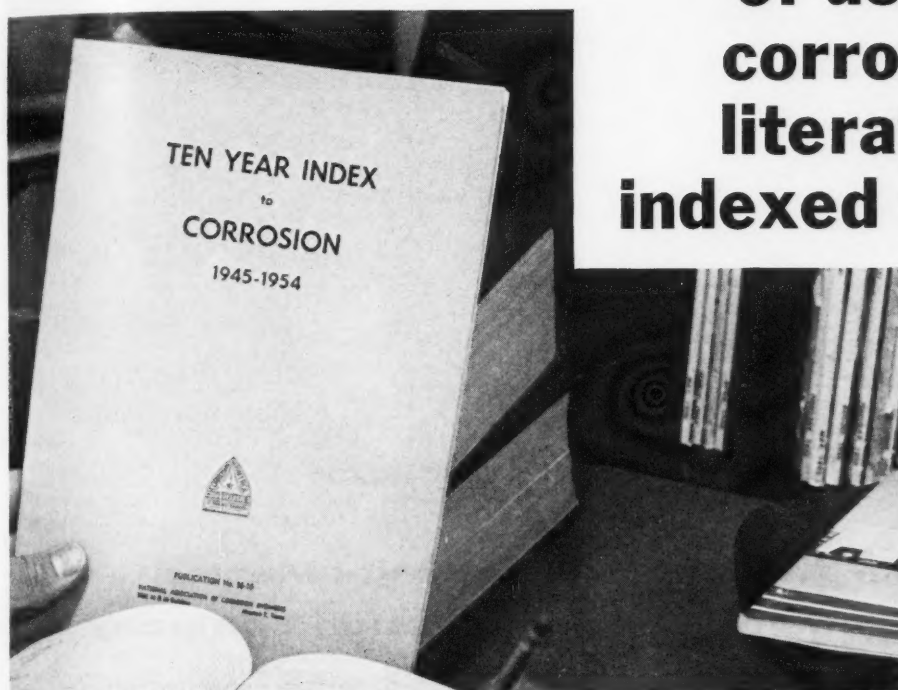
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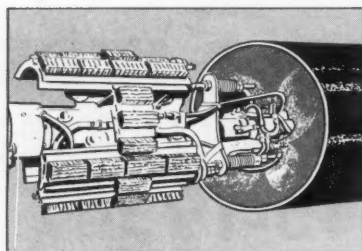
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## NACE NEWS

# 23 Papers Listed for San Antonio Meeting

## Topics Important To Southwest Are Covered in Program

Six symposia comprising 23 papers are included in the technical program to be presented during the South Central Region Annual Meeting in San Antonio. The October 23-26 meeting also is scheduled to have numerous technical committee meetings and a full program of entertainment.

Norman Hackerman, University of Texas, technical program chairman, gave the following tentative program for the session's symposia:

### Thursday, October 25

**Corrosion in the Pipe Line Industry**—Loyd B. Nelson, Shell Pipe Line Corp., Houston and A. L. Stegner, Tennessee Gas Transmission Co., Houston chairman and vice-chairman.

**Effects of Variables in Laboratory Testing of Corrosion Inhibitors for Refined Petroleum Products**, David D. Boies and J. L. Bregman, National Aluminate Corp., Chicago.

**Use of Organic Inhibitors in Corrosion of Copper in Nitric Acid**, Fernando Macias Rendon, Instituto Tecnológico, Monterrey, N. L., Mexico.

**Cathodic Protection of Compressor Stations**, Pearce R. Butterfield, Transcontinental Gas Pipe Line, Houston.

**A Case History of High Temperature on a Gas Transmission Line**, A. T. Surber, Trunkline Gas Co., Houston.

**Elevated and High Temperature Corrosion**—E. Q. Camp, Humble Oil & Ref. Co., Baytown, Texas, chairman.

**High Temperature Oxidation of Iron-Nickel Alloys**, C. E. Birchenall, James Forrestal Research Center, Princeton University, N. J.

**Effect of Hot H<sub>2</sub>S Environment on Various Metals**, F. J. Bruns, Sinclair Res. Lab., Inc.; Harvey, Ill.

**High Temperature H<sub>2</sub>S Corrosion in Catalytic Refining**, Cecil Phillips, Humble Oil & Ref. Co., Baytown, Texas.

**The Nature of Zirconium Corrosion in Water Above 200 C**, R. D. Misch, Argonne National Lab., Lemont, Ill.

**Corrosion in Oil and Gas Well Equipment**—W. F. Oxford, Jr., Sun Oil Co., Beaumont; J. L. Battle, Humble Oil & Ref. Co., Houston, chairman and vice-chairman.

**Introductory Remarks**, C. C. Nathan, The Texas Co., Bellaire, Texas.

**Factors to be Considered in Evaluating Corrosion Inhibitors**, E. J. Simmons, Sun Oil Co., Dallas.

**Chemical Principles and Corrosion Reactions**, Norman Hackerman, University of Texas, Austin.

(Continued on Page 90)



**SOME HEAD TABLE GUESTS** at the recent joint meeting of the Vancouver Section NACE and Vancouver Section, Chemical Engineering Div., Chemical Institute of Canada at Hotel Georgia, Vancouver. Shown here are, left to right, John McLaughlin, Industrial Coating, Ltd., vice-chairman Vancouver Section NACE; John Hurley, representing the American Society for Metals; Frank G. Mitchell, Ellett Copper and Brass Co., Ltd., Vancouver NACE Section chairman; C. H. Fellows, president of American Society for Testing Materials, guest speaker at the meeting.

## Loper and Verink Accept 1958 Conference Posts

D. R. Loper, Standard Oil Co. of California, San Francisco, Cal., has accepted the post of general chairman of the 1958 Fourteenth Annual NACE Conference and Exhibition to be held March 17-21 at San Francisco. Ellis D. Verink, Jr., Aluminum Company of

America, New Kensington, Pa., has accepted the post of technical program chairman for this conference.

Mr. Verink will serve as vice-chairman of the 1957 St. Louis NACE Conference as is the custom.

Copies of Corrosion's 10-Year Index can be ordered now.

NACE's Abstract Card service has issued more than 10,000 cards.

## Tentative Orders Being Taken for Yearbook

Tentative orders accompanied by remittance are being accepted at Central Office NACE for copies of the 1956 NACE Yearbook which includes the membership directory, directory of technical committees and certain other information about the association. Members in good standing were sent a card inquiry June 1. Tentative orders will be accepted until August 1.

If the number of orders on hand then indicates the yearbook can be published at nominal or no cost to the association

it is contemplated that work on the directory will proceed. If insufficient orders are received the decision not to publish the directory probably will be made.

It is urged that members interested be sure that their remittances accompany their request for copies. The yearbook is being offered only to members of NACE.

Members who wish to do so may use the coupon elsewhere in this issue of CORROSION to send in orders.

### ORDER FOR 1956 YEARBOOK

This is an inquiry to NACE members to ascertain if they desire a copy of the 1956 Yearbook which will contain a Membership Directory. If so, the return of this card signed by an NACE member with a remittance of \$1.50 will constitute an order. If sufficient orders are not received to justify printing the Yearbook the remittance will be returned. Return this card Signed to National Association of Corrosion Engineers, 1061 M & M Bldg., Houston 2, Texas.

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AT CHICAGO SECTION'S May 15 meeting, top, left to right, R. B. Janota, Swift and Co., chairman; F. L. Whitney, Jr., Monsanto Chemical Co., St. Louis, principal speaker; R. W. Flournoy, Corn Products Co., past-chairman; I. J. Acosta, Crane Co., treasurer. Bottom, hosts at the Fellowship Hour, left to right, A. F. Pasowicz, H. L. Dibble, J. J. Kaneski and D. R. Walser, Wright Chemical Corp.

## Whitney Talks on Plastics at Chicago Meeting

Principles applicable to the use of plastics in engineering installations were defined in some detail at the May 15 meeting of Chicago Section by F. L. Whitney, Jr., Monsanto Chemical Co., St. Louis. Mr. Whitney's principal point was that formal engineering principles can be applied satisfactorily to the problems associated with plastics use.

The section now has 326 members and

28 corporate members on its roster. Newly elected officers are R. B. Janota, Swift & Co., chairman; V. M. Kalhauge, Standard Oil Co. (Ind.), vice-chairman; H. C. Boone, People's Gas Light & Coke Co., secretary and I. J. Acosta, Crane Co., treasurer.

The three steps involved in considering plastics on an engineering basis are: Laboratory screening, pilot plant or

field testing and plant installation. Mr. Whitney illustrated these steps by specific examples including tests of vinyl laminates for tank car service, vinylidene chloride-Buna N formulation for pipeline service and polyester and glass laminates for storage tank service. Environments included phosphoric acid and fertilizer solutions. A representative field evaluation program covered a five year study to determine the effectiveness of polyester glass fiber panels for cooling water tower service.

Mr. Whitney also reviewed 17 field installations involving the use of polyvinyl chloride, polyester-glass laminates, polyethylene, furan impregnated glass tapes, molded phenolics containing cloth, asbestos and carbon; armored Pyrex pipe employing epoxy impregnated glass tape and polyester-glass windows and doors. A wide variety of environments was involved.

## 23 Papers Listed—

(Continued From Page 89)

Corrosion Measurements in an  $H_2S$ — $H_2O$  Absorption Pilot Plant, B. W. Bradley and N. R. Dunne, Shell Oil Co., New York, N. Y. and Calgary, Canada.

Adaptation of Cathodic Protection to the Splash Zone, M. A. Riordan, Rio Engineering Co., Houston.

Corrosion in the Utilities Industry—Glyn W. Beesley, Dallas Power and Light Co., Dallas; P. Ray Harrell, Southwestern Bell Tel. Co., Dallas, chairman and vice-chairman.

Corrosion in Power Plants, Harry Blackwell, Texas Electric Service Co., Fort Worth.

Corrosion Control in the Utility Industry, A. W. Peabody, Ebasco Services, Inc., New York.

Chemical Corrosion of Lead Cable Sheaths, W. W. Elley, Southwestern Bell Telephone Co., San Antonio.

Procedures to Increase Pipe Line Enamel Coating Standards, E. C. Rogness, Lone Star Gas Co., Dallas.

Friday, October 26

Cathodic Protection—M. E. Parker, Cor-mit Engineering Co., Houston, chairman.

The Copper Sulfate Electrode, Gordon N. Scott, Consultant, Los Angeles, Cal.

Why Are We Interested in Rectifier Efficiency?, R. M. Wainwright, Good-All Manufacturing Corp., Oglala, Neb.

High Silicon Anodes for Cathodic Protection, W. T. Bryan and W. A. Luce, Duriron Co., Dayton, Ohio.

Cathodic Protection of Oil Well Casing, Yale Titterton, Corrosion Services, Inc., Tulsa.

Corrosion in Transportation Industry—J. R. Spraul, General American Transportation Corp., East Chicago, Ind.

Internal Protection of Ships, L. P. Sud-rabin, Electro Rust-Proofing Corp., Belleville, N. J.

External Ship Hull Protection, C. F. Schrieber, Dow Chemical Co., Freeport, Texas.

Chemically Deposited Nickel Alloy Tank Coatings for Commodity Transport, W. J. Crehan, General American Transportation Corp., Chicago.

Topical Indices to the material published in the Technical Section of Corrosion are published annually in the December issue.

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# Northeast Region Fall Meeting to Have 12 Papers

## Four Symposia Are Set for Sessions At Philadelphia

Twelve technical papers in four symposia have been scheduled for the Northeast Region 1956 Fall Corrosion Conference at Philadelphia. The meeting will be held October 15-17 at the Drake Hotel. First day of the meeting has been set aside for meetings of technical committees.

Symposia have been scheduled on protective coatings; experimental design, analysis and application; plastics and new alloys and cermets.

The tentative program has been given as follows:

### Tuesday, October 16

**Protective Coatings**—J. H. Cogshall, Pennsylvania Salt Manufacturing Co., Philadelphia, Pa., chairman.

**Chemical Surface Preparation of Structural Steel**, J. H. Lawrence, Jenolite Ltd., London, Eng.

**An Examination of Epoxy Type Industrial Maintenance Coatings**, W. M. Brackett, Truscon Laboratories, Div., Devco & Reynolds Co.

**Capitalized Costs for Painting**. (Speaker to be named).

**Experimental Design, Analysis and Application**—J. J. Hur, The Atlantic Refining Co., Philadelphia, Pa.

**Design of Experiments**, John D. Hromi, U. S. Steel Corp., Research and Development Laboratories, Monroeville, Pa.

**Analysis of Multiple Variance**. (Speaker to be named).

**Practical Application of Statistical Analysis**, J. G. Jewell, Gulf Res. & Dev. Co., Pittsburgh, Pa.

### Wednesday, October 17

**Plastics**—Walter H. Burton, General Chemical Div., Allied Chemical & Dye Corp., Camden, N. J.

**What Is New In Corrosion Control With Teflon?**, George C. Nielsen, E. I. duPont de Nemours & Co., Poly-Chemicals Dept., Wilmington, Del.

**New Elastomeric Materials of Construction**, James P. McNamee, U. S. Rubber Co., Providence, R. I.

**Plastics in the Chemical Industry**, H. E. Atkinson, E. I. duPont de Nemours & Co., Engineering Dept., Wilmington, Del.

**New Alloys and Cermets**—J. Byron Godshall, Ingersoll-Rand Co., Easton, Pa.

**Low Nickel and Nickel-Less Stainless Steels**, W. G. Renshaw, Alleghany-Ludlum Steel Corp., Breckenridge, Pa.

**Fabrication of Titanium**, Richard Avery, The Pfadler Co., Rochester, N. Y.

**Selection of Ceramics and Cermets**, L. R. McCreight, General Electric Co., Schenectady, N. Y.



There ARE Effective Inhibitors for Corrosion...

## Exhibition is Scheduled For San Antonio Meeting

An exhibition will be held in the Crystal Ballroom of the Gunter Hotel, San Antonio, in connection with the South Central Region Annual meeting there October 23-26. Arrangements have been made for approximately 50 booths ranging in size from 5 by 6 to 9 x 10 feet.

Prospective exhibitors will be sent a contract and specifications soon. One letter of inquiry has been sent already to determine what interest there is in the exhibit. This is the first time an NACE-sponsored exhibit has been held at a regional meeting.

The San Antonio exhibition is intended to meet requests for exhibitors in South Central Region many of whom prefer not to have exhibits at national NACE meetings. It is not intended to be a substitute for or an alternate to the annual exhibition held in connection with the national meeting each March.

## Mrs. Young Heads St. Louis Ladies Program Committee

Mrs. Mary Ellen Young, Webster Groves, Mo. has been named chairman of the Ladies' Program Committee for the NACE 13th Annual Conference at St. Louis March 11-15, 1957.

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## Five Past Presidents of NACE to Take Part In Ohio State University Corrosion Course

Nationally known experts in several fields of corrosion work are on the program for a short course to be given during the week of September 10 at Ohio State University, Columbus. Five past-presidents of NACE are on the faculty. The five-day course covers discussions on fundamentals, inhibitors, cathodic protection, high temperatures, design, types of corrosion, testing and

evaluation, petroleum refinery corrosion, coatings, materials selection, plastics and a tour of the university laboratories.

This is the first formal short course on corrosion to be given at Ohio State University. The National Association of Corrosion Engineers is cooperating with the university in presenting it. Plans have been made to present certificates and provide dormitory housing on the campus. Enrollment is limited to 150 and the fee has not been decided yet.

A tentative program follows:

### Monday, September 10

Fundamentals of Corrosion, Physical and Electrochemical Factors, Norman Hackerman, University of Texas.

Fundamentals of Corrosion, Metallurgical and Mechanical Factors, M. G. Fontana, Ohio State University Inhibitors, Principles, Norman Hackerman.

### Tuesday, September 11

Cathodic Protection, Principles, A. W. Peabody, Ebasco Services, Inc., New York.

Oxidation and Structural Stability at High Temperatures, A. deS. Brasunas, Metals Engineering Institute, Cleveland.

Cathodic Protection Practical Application and Economics, A. W. Peabody. Design of Equipment to Prevent Corrosion, R. B. Mears, U. S. Steel Corp., Pittsburgh.

### Wednesday, September 12

Chemical Treatment of the Environment for Corrosion Prevention, A. Wachter, Shell Development Co., Emeryville, Cal.

Types of Corrosion, Diagnosis and Treatment of Corrosion Problems, M. G. Fontana.

Corrosion Testing and Evaluation, A. Wachter.

Petroleum Refinery Corrosion, R. W. Manual, Socony Mobil Oil Co., Inc., New York City.

(Continued on Page 93)

### POSITIONS WANTED and AVAILABLE

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Edward C. Rue, Chairman; Boston Edison Company, 182 Tremont Street, Boston 12, Massachusetts  
Wayne H. Keller, Vice-Chairman; 101 Devonshire Road, Waban 68, Massachusetts  
Manson Glover, Secretary-Treasurer; Glover Coating Company, Inc., 376 Washington Street, Malden 48, Massachusetts

### • New Orleans-Baton Rouge Section

R. M. Robinson, Chairman; Continental Oil Company, P. O. Drawer 68, Harvey, La.  
O. L. Grosz, Vice-Chairman; The California Company, P. O. Box 128, Harvey, La.  
W. J. Eads, Secretary-Treasurer; Products Research Service, Inc., P. O. Box 6116, New Orleans 14, La.  
Lee N. Spinks, Trustee; Catholic Protection Service, 1634 Roberts Street, New Orleans 15, La.

The complete directory of regional and sectional officers will be published next in the August issue. Next publication of Technical Committee Directory will be in September.

### NORTH CENTRAL REGION

H. F. Haase, Director; Corrosion Consultant, 2202 South 28th Street, Milwaukee, Wisconsin  
W. J. Ries, Chairman; Tretolite Company, St. Louis 18, Missouri  
R. I. Lindberg, Vice-Chairman; Sinclair Research Laboratories, Inc., 400 East Sibley Blvd., Harvey, Illinois  
L. D. Cook, Jr., Secretary-Treasurer; 8665 Kenberton Drive, Oak Park, Michigan

### • Sabine-Neches Section

Jesse J. Baker, Chairman; Magnolia Petroleum Company, P. O. Box 3311, Beaumont, Texas  
A. V. Wafer, Vice-Chairman; Ohmstede Machine Works, P. O. Box 1288, Beaumont, Texas  
Paul McKim, Secretary-Treasurer; Socony-Paint Products Company, P. O. Box 2648, Beaumont, Texas

### SOUTH CENTRAL REGION

John Edward Loeffler, Trustee-at-Large; Thornhill Craver Company, P. O. Box 1184, Houston 1, Texas

## HALF-YEAR MEMBERSHIPS AVAILABLE

Active membership in the National Association of Corrosion Engineers for the six months July-December, 1957 inclusive is available at \$6. Membership includes copies of CORROSION and all other privileges. Applications may be obtained on request from A. B. Campbell, Executive Secretary, National Association of Corrosion Engineers, 1061 M & M Bldg., Houston 2, Texas.

## Sixth Annual Shreveport Short Course Sept. 20-21

A committee has been named by Shreveport Section to conduct its Sixth Annual Corrosion Control Short Course. Scheduled for Thursday and Friday, September 20-21 on the campus of Centenary College, Shreveport, the course is designed to interest superintendents, field men and corrosion engineers. A banquet and entertainment will be held Thursday night and a field trip Friday afternoon will demonstrate corrosion control on pipe lines and gas wells.

The committee is as follows: Lionel Morrow, Interstate Oil Pipe Line Co., general chairman; John Wise, Arkansas-Louisiana Gas Co., and Ed Sullivan, United Gas Pipe Line Co., respectively program chairman and vice-chairman; Mike Deodati, United Gas Pipe Line Co. and Ned Stearns, D. E. Stearns Co., respectively chairman and vice-chairman banquet and entertainment; Justin Griffith, Texas Eastern Transmission Co. and Frank Bickham, Irish Engineering Co., chairman and vice-chairman respectively local arrangements; Bob Naremore, Arkansas Fuel Oil Corp. and Jim Butler, Arkansas Louisiana Gas Co., respectively chairman and vice-chairman mail and publicity.

## Central New York Section Elects Officers for Year

The annual election of officers of Central New York Section was held May 18 at Watertown, New York. The following officers were elected to be installed June 23 at the annual business meeting:

F. C. Jelen, Solvay Process Division, Allied Chemical & Dye Corp. Syracuse, New York, chairman. Orrin Broberg, Lamson Corp. Syracuse, New York, vice-chairman; Jack Yates, Niagara Mohawk Power Corp., Syracuse, New York, secretary-treasurer.

## Five Past Presidents —

(Continued From Page 92)

Thursday, September 13

Protective Coatings, Principles, E. E. McSweeney, Battelle Memorial Institute, Columbus, Ohio.

Selection of Materials of Construction, F. L. Whitney, Jr., Monsanto Chemical Co., St. Louis, Mo.

Reducing Maintenance Painting Costs, M. L. Monack, E. I. duPont de Nemours & Co., Inc., Wilmington, Del.

Role of the Corrosion Engineer in Industry, F. L. Whitney.

Plastics and Other Non-Metallic Materials, M. L. Monack.

Friday, September 14

Corrosion by Liquid Metals, W. D. Manly, Union Carbide Nuclear Co., Oak Ridge, Tenn.

Corrosion by Aqueous Environments at High Temperature, F. H. Beck, Ohio State University.

Luncheon and presentation of certificates, F. L. LaQue, The International Nickel Co., Inc., New York.

Corrosion in Action, International Nickel Co., Inc. motion picture.

Tour of laboratories at Ohio State University.

## Soil Box Demonstrated at Philadelphia Meeting

M. C. Miller, Allendale, N. J. presented a Soil Box Demonstration at the May 11 meeting of Philadelphia Section.

A past chairman's certificate was presented to John S. Pettibone, American Society for Testing Materials.

About fifty members were present.

## Farmer Moved to N. Y.

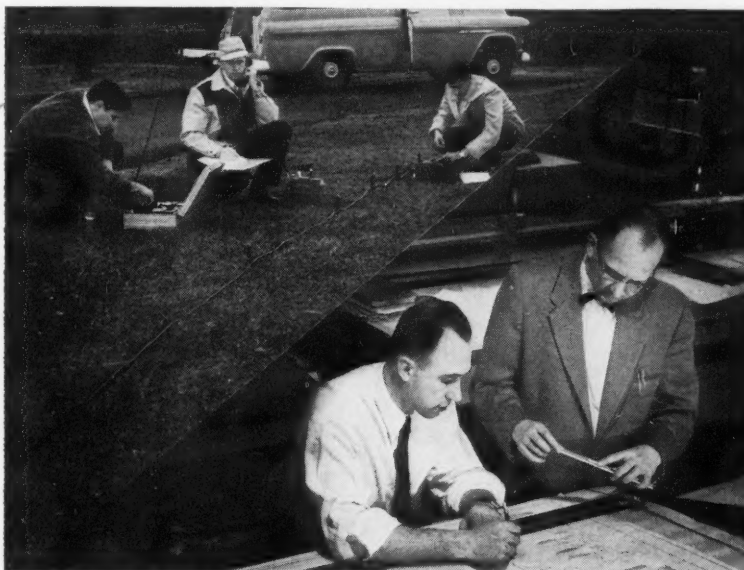
Howard N. Farmer, Jr., has resigned as secretary-treasurer of Western Region because International Nickel Company has transferred him to its offices in New York City. Mr. Farmer formerly was with International Nickel Company's Los Angeles office.

## Boston Section Hears Talk On Organic Coatings

Functional classification of organic coatings which permit their selection to meet the requirements of a given environment and use were discussed at the May 2 meeting of Greater Boston Section. Kenneth Tator, Kenneth Tator Associates, Coraopolis, Pa. was the speaker before about 60 members and guests at Beaconsfield Hotel, Brookline.

Following are section officers for 1956-57: Edward C. Rue, Boston Edison Co., chairman; Wayne H. Keller, National Research Corp., vice-chairman and Manson Glover, Glover Coating Co., secretary-treasurer.

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## Protection of Tuna Ships Is Topic at San Diego

The May 23 meeting of San Diego Section at the Bali Hai Club featured two speakers: A. E. Codina, A. E. Codina Company and D. P. Armbruster, San Diego Gas & Electric Company. Mr. Codina spoke on The Practical Approach in the Application of Protective Coatings. He dealt mainly with corrosion problems and protection of boats in the tuna fishing fleet. The presentation was illustrated by slides giving before and after comparisons. He spoke first of the various problems which make protection of the fishing boats difficult and then discussed many of the problems he encounters, the method of correction and results after the boats have been in service for a time.

Mr. Codina pointed out several innovations he has made and many of the pitfalls he has encountered during his years of experience.

Mr. Armbruster presented a short resume of seven papers which were given at the La Jolla Marine Corrosion Conference, paying particular attention to the conclusions of the authors. Those discussed were about practical aspects.

## Permian Basin Section Hears Sharpe on Coatings

"A Review of Protective Coatings in the Permian Basin," was the subject of L. G. Sharpe, Napko Paint and Varnish Works, Midland, Texas before 45 members and guests of Permian Basin section May 11.

## Post Convention Tour of Mexico Being Arranged

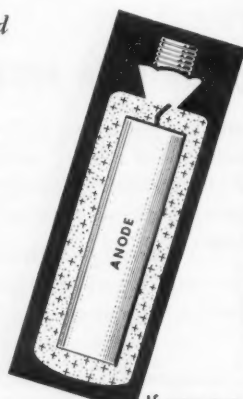
A post convention tour of Mexico is being arranged by officials in charge of arrangements for the South Central Region Annual Meeting in San Antonio October 23-26. Alamo Section NACE has made arrangements with American Airlines for a post-convention trip to Mexico City. A chartered flight will be made available if sufficient interest is shown.

Those who drive to San Antonio are reminded that the border of Mexico is only 150 miles from the city and that beautiful Monterrey, Mexico is but 145 miles further. It is recommended that those considering such a trip check with appropriate agencies regarding insurance and tourist requirements.

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## PAPERS APPROVED FOR PUBLICATION IN CORROSION

- Selection and Application of Coatings in the Pulp and Paper Industry by Raymond B. Seymour
- Corrosion Resistant Aluminum Above 200° C by J. E. Draley and W. E. Ruther
- Aqueous Corrosion of 2S Aluminum Up to 200° C by J. E. Draley and W. E. Ruther
- A Laboratory Method for the Evaluation of Oil Production Corrosion Inhibitors by David B. Boies
- Intrinsic Protection of Water Mains by M. Unz
- Corrosion Engineering Problems in High Purity Water by D. J. DePaul
- Magnetic Amplifier Type Recording Instrument for Electrolysis Survey by Michio Tanaka, Jiro Yamaguchi and Yoshifumi Sakurai
- Earth Potential or Surface Potential Gradient Tests on Buried Cable by Daniel R. Werner
- An Estimate of Corrosion Losses to Underground Cable and Pipeline in Japan by Michio Tanaka
- Attack of Scaling-Resistant Materials by Vanadium Pentoxide and Effects of Various Alloying Elements Thereon by E. Fitzner and J. Schwab
- The Role of Crevices in Decreasing the Passivity of Titanium in Certain Solutions by David Schlain and Charles B. Kenahan
- Application of Cathodic Protection to 48 Well Casings and Associated Production Facilities at Waskom Field by G. L. Doremus, W. W. Mach and Joseph L. Lawnick
- Field Laboratory Testing of Wrappings for Buried Structures by H. M. Clayton
- The Effect of Contamination by Vanadium and Sodium Compounds on the Air-Corrosion of Stainless Steel by George W. Cunningham and Anton de S. Brasunas
- Corrosion Control Practices for Pipe-Type Cables on the Detroit Edison System by W. A. Sinclair
- Behavior of 18-8 Stainless Steel in 2N Boiling Nitric and Sulfuric Acid Mixtures by P. E. Krystow and M. Balicki
- Two Cases of Corrosion in Suburban New York Disguised as Galvanic—Their Cause and Mitigation by W. Searle Woodward
- Steel Surface Properties Affect Internal Corrosion Performance of Tin Plate Containers by A. R. Willey, J. L. Krickl and R. R. Hartwell

## Corrosion Engineer Views Plans of San Diego Water Department

The San Diego Water Department corrosion engineer inspects plans for new construction. P. Beerman, Director of the Water Department, San Diego, Cal. reported at the LaJolla April 18-21 Conference on Marine Corrosion Problems held at the Scripps Institution of Oceanography. "It took many years for us to wake up and recognize the importance of this (corrosion) problem, not only from the cost standpoint, but also from the public relations effect. Corrosion causes breakdowns and breakdowns affect service," Mr. Beerman said.

Mr. Beerman reported the San Diego water department is now replacing from 600,000 to 700,000 feet of cast iron pipe that "reached the end of their economic life long before their ordinarily estimated life span."

The speaker also related some of the history of corrosion on San Diego's water system, including some unhappy experience concerning installation of corrosion control systems by inexperienced personnel. Specific problems mentioned by Mr. Beerman included galvanic corrosion resulting from the use of copper service lines, difficulties with alternating current grounding to water mains, corrosion damage to gate valves, meters, filtration systems, swimming pools, sewage treatment plants and a fire boat.

"Corrosion control is becoming a highly complex science. Gone are the days when a young electrician and or ambitious helper can be charged with a program to control corrosion. The program now requires thorough analysis.

"Neither is corrosion something for intermittent consideration. Corrosion continues to attack a system every day of the year and constant effort is needed to mitigate and reduce the losses. The experience at the Alvarado Filtration Plant is an example of benefits gained by thorough analysis by experienced engineers. In 1950, the plant was placed in operation. One year later severe corrosion was observed on several of the shafts in the basins, and cathodic protection was installed by inexperienced personnel.

"Many thousands of dollars were spent in this work and still no protection was provided for the corroding shafts. Another survey and design by experienced personnel was necessary. The second protection system was installed early in 1953 and has operated satisfactorily since that time. Frequent inspections are made and have shown the metallic structures to be free from corrosion," Mr. Beerman said.

## Riegel Paper Plant Toured

The Milford, New Jersey plant of the Riegel Paper Company was toured by 28 members of Lehigh Valley Section May 26. Section members, guided by Riegel's personnel manager, Mr. Opdyke, saw the eleven machines making a wide range of specialized papers, including semi-transparent glassines, which comprise most of the plant's production.

Luncheon was served at Riegel Ridge, the company's recreation center.



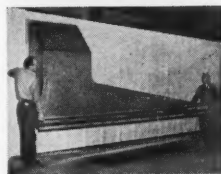
# News

## Wherever CORROSION RESISTANCE is a Factor HAVEG... Industry's Standard For CONQUERING CORROSION



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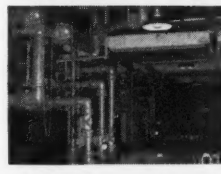
### in FUME REMOVAL

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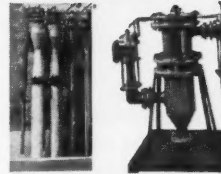
### in CHEMICAL FLOORING

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### in PROCESS PIPE AND FITTINGS

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## Test Panel's Use Described At Detroit Section Meeting

Correlation of results achieved with the KTA test panel with actual service of coatings is good, Kenneth Tator, Kenneth Tator Associates, Coraopolis, Pa. told Detroit Section at its May 24 meeting. Mr. Tator spoke to about 50 members and guests on "A New Concept of Paint Evaluation."

Development of the test panel and his method of evaluating coating was stressed by the speaker. He cited the 12 features of the panel which correspond to parts of plant structures which show early paint failure. By correlating the beginnings of edge and plane surfaces failure, Mr. Tator said he can determine the time when a structure should be

repainted with a given system with minimum surface preparation; when it is imperative to paint without further delay and frequency of painting. He said his presentation was the first before any audience of the details of the KTA system.

Robert P. Marshall, Saran Lined Pipe Co. and Eugene V. Ivanso, Detroit Testing Laboratory were named NACE members on the Engineering Society of Detroit Joint Council.

## Portland Section's Topic is Kraft Digester Corrosion

Rapid corrosion rates in cavities behind stainless steel liner plates in Kraft paper digesters was discussed at a June 7 meeting of Portland Section. About



**THIS MERRY GROUP** is shown during the Fellowship Hour at the Southeast Region May 3 meeting at Atlanta. They are, left to right, A. T. Storrey, Atlanta Water Works; Herbert Van Noughs, Southeastern Pipe Line Co., Atlanta; Robert A. Davis, Chicago Bridge & Iron Co., Birmingham, Ala.; Arthur B. Smith, Amercoat Corp., Jacksonville, Fla.

30 members and guests heard Sam Knapp, Hawaiian Sugar Planters Association, talk on "Corrosion Testing and Mitigation in Kraft Mill Digesters."

The illustrated paper was the result of a study made at a plant of the Gaylord Container Corp. When the digester liners cracked cavities between the liner and the vessel wall filled with liquor during digesting and emptied when pressure was released.

Another discussion on the same general topic, "How Weyerhaeuser Renew Digesters," was given by Newton Betts.

## Sabine-Neches Section

Relaxation was the order of the day at the May 26 meeting of Sabine Neches Section in Orange, Texas. Twenty-two members and guests attended to elect new officers and see three motion pictures. New officers elected were: J. J. Baker, Magnolia Petroleum Co., chairman; A. Wafer, Ohmstede Machine Works, vice-chairman; Paul McKim, Socony Paint Products, treasurer.

Films were shown on hunting, fishing and a travelogue. The section meets again in September.

## Cleveland Section Has TV Program About Corrosion Control

Cleveland Section provided a program entitled "Corrosion Control" over Station KYW, Channel 3, Cleveland on June 2. The program was one of a series presented every Saturday evening sponsored by Cleveland Technical Societies' Council designed to interest high school students in engineering as a profession.

The June 2 program was presented as a story with the following cast:

John Scott (Truston Laboratories) played the part of a factory manager setting aside thousands of dollars for corrosion repairs and wondering what could be done to reduce the outlay.

Bruce Hooper (Cuyahoga Heights High School) represented a science teacher visiting the factory in the interest of his science students.

S. W. McIlrath (Diamond Alkali Co.) was the factory corrosion engineer who conducted the science teacher around to show him the various aspects of corrosion.

R. C. Weast (Case Institute of Technology) demonstrated and explained the electrochemical aspects of corrosion.

Oliver Henderson (The Ohio Bell

(Continued on Page 98)

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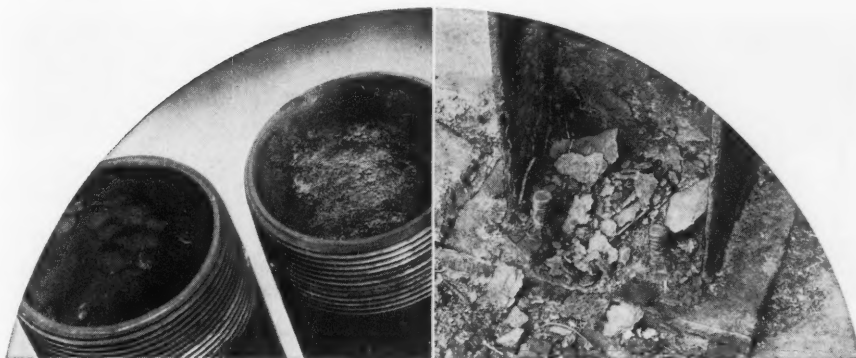
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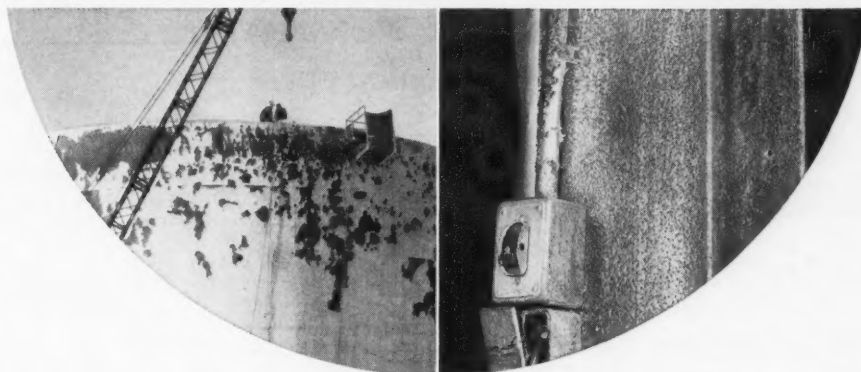
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NEW OFFICERS of Houston Section are shown (top, left to right) Alvan E. Richey, Cathodic Protection Service, Houston, trustee; C. L. Woody, United Gas Corp., chairman and Joy Payton, The Texas Company, vice-chairman. Willard B. Scott, director of research, Crest Research Laboratories, (left) describes his company's recently developed instrument for continuous measurement of corrosion.



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All three units listed above for \$2, payment in advance. Add 65c for book post registry to addresses outside the U. S., Canada and Mexico. Address orders and make remittances payable to National Association of Corrosion Engineers, 1061 M & M Bldg., Houston 2, Texas. Articles may be purchased separately.

## New Way to Test Inhibitors Explained To Houston Section

First meeting under newly elected officers of the Houston Section will be held August 14, at John's Restaurant, 9350 S. Main. There will be no section meeting in July. Norman Hackerman, University of Texas, will be the technical speaker for the August meeting. He will talk on corrosion fundamentals.

Installation of new officers for the 1956-'57 term and a technical talk on "Laboratory Tests and Data Relevant to Field Application of Corrosion Inhibitors" by Willard B. Scott, director of research, Crest Research Laboratories were features of the June 12 meeting.

### New Officers Take Over

C. L. Woody, United Gas Corp., newly elected section chairman presided over the meeting after his introduction by retiring chairman Alvan E. Richey, Cathodic Protection Service. Other new officers assuming their duties were introduced. They are: Joy Payton, The Texas Co., vice-chairman and Bill Wood, Jr., Products Research Service, Inc., secretary-treasurer. Richey is section trustee. Chairmen of the various activity committees will be named by the section officers and will be introduced at the August meeting.

For the technical part of the meeting, Mr. Scott gave an illustrated talk on laboratory testing of inhibitors. He showed a diagram of apparatus to provide continuous testing consisting of a glass cylinder equipped with three inlet ports at the bottom for separate injection of oil, gas, and water. Two outlets, one for gas at the top and a liquid outlet in the side near the top make possible continuous testing of corrosion products. Effluent gas is tested by the hydrogen evolution method. Discharged water can be tested also.

Agitator vanes in the bottom help mix the test solution and keep it in motion around the test coupon and through the apparatus. Mr. Scott showed curves obtained by testing inhibitors. He pointed out that it often is economical to employ a high concentration of inhibitor

when using the batch treatment method, depending on the persistency of the inhibitor after the period of injection to give protection.

The speaker also described a new apparatus called the Corrosometer for testing rates of corrosion. The machine works on the principle of change in electrical resistivity of a metal due to corrosion. A probe is inserted in the corrosive environment. The instrument measures the change in electrical resistance and indicates the results in microinches of metal lost. The machine is sensitive and results it gives have a close correlation to results obtained by other laboratory methods and from actual field experience, he said.

Approximately 100 persons attended the meeting, 10 of them guests.



## NATIONAL, REGIONAL MEETINGS and SHORT COURSES

### 1956

Oct. 15-17—Northeast Regional Meeting, Philadelphia.

Oct. 23-26—South Central Region, Gunter Hotel, San Antonio, Texas.

Nov. 15-16—North Central Region Meeting, Detroit, Mich.

### 1957

Mar. 11-15—NACE Annual Conference, Kiel Auditorium, St. Louis, Missouri.

### 1958

Mar. 17-21—NACE Annual Conference, Civic Auditorium, San Francisco, California.

### 1959

NACE Annual Conference, Sherman Hotel, Chicago, Illinois.

### SHORT COURSES

### 1956

Sept. 10-14—Corrosion Short Course, Ohio State University, Columbus.  
Sept. 20-21—Sixth Annual Corrosion Control Short Course, Shreveport Section, Centenary College, Shreveport, La.

## Cleveland Section—

(Continued From Page 96)

Telephone Co.) displayed and discussed various corroded objects and related resulting corrosion expense added to the cost of commodities, wages and the like.

A. R. Corlett (Harco Corp.) displayed and explained the various remedial measures, such as coatings, wrappings, and cathodic protection.

S. W. McIlrath then displayed and discussed the place of plastics in corrosion prevention.

Dr. Weast closed the program with a brief summary of the recommended qualifications and training that are essential to those interested in corrosion control as an engineering profession.

A copy of the script has been sent to Central Office NACE from which it may be borrowed by NACE sections interested in presenting a similar television program.



## GENERAL NEWS

# Foreign Corrosion Activities Reported to ISCC

## 70-Year-Old Wrought Iron Water Tank Found In Excellent Condition Before Demolition

A wrought iron water standpipe, erected in either 1883 or 1886 by A. M. Byars Co., was found to be virtually undamaged by corrosion when razed during the spring of 1956. The riveted tank, with a capacity of 800,000 gallons was used as a water supply tank for the first 50 years of its life and during the last 20 years or so as a "floating" tank to equalize water pressure in downtown Houston mains at 74 psi.

Until 1955, potable water pumped through Houston's system was from underground sands. In that year surface water from a lake constructed some 20 miles from the city was turned into some of the mains. The greater part of Houston's water still is obtained from wells.

An examination of the inside of this tank (Figures 1 and 2) showed that while there was some slight tuberculation, the plates were virtually in the same condition as they were when originally fabricated. Figure 1 was taken at a point about 15 feet from the floor of the tank. A calcareous scale covered the surface uniformly, with occasional tubercles. Rivets were in good condition.

Figure 2 shows a manhole cut through the tank walls at the ground level. Examination of the edges of this cut showed very little pitting and that superficial.

Figure 3 shows the tank just before razing began. The wrecker's crane is seen at one side. An examination of the outside, which had not been repainted for some years, showed little, if any,



Figure 1—About 14 feet from the bottom the inside tank walls were covered with a continuous layer of rust. Tubercles may be seen as darker spots against the rust, which probably contained some lime.

indication of leaks. Rivets of the first three or four courses appeared in excellent condition. Some rivets in the upper courses had corroded away and been replaced with bolts. A soft lead washer was cramped under inside bolt heads.

Houston water department engineers said the tank had been painted inside at one time. A steel roof was added about 1937, in part to prevent the tank being used as a swimming pool by boys in the neighborhood.

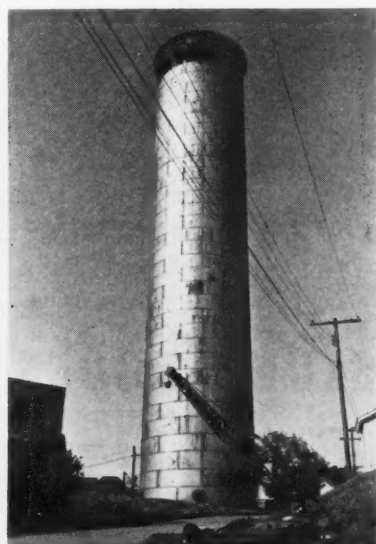


Figure 3—The tank, shown here just before demolition started, was a landmark of downtown Houston for more than 70 years.

## New Organizations, Cooperation Are Outstanding Gains

Following are reports of activity in corrosion control received from correspondents of the Sub-Committee on Foreign Relations of the Inter Society Corrosion Committee. F. L. LaQue, The International Nickel Co., Inc. is chairman of the sub-committee.

All of the reports cover activities during 1955 with the exception that the Union of South Africa report includes work done during 1954 and 1955. Names of the correspondents are given.

**BELGIUM**—M. Pourbaix, director, Centre Belge d'Etude de la Corrosion, Brussels.

**Association des Industriels de Belgique.** Most of the industrial works in Belgium are being visited by representatives of this organization. Help is being given in measures to improve health and security and reduce accidents. The Corrosion Section of AIB gives technical advice on corrosion prevention.

**Association Assurance Peinture Anti-Corrosion.** Insurance coverage on the protection given by paints is being offered.

**Centre Belge d'Etude et de Documentation des Eaux (Cebedeaux).** A committee on rust is working on micro-analysis of rust specimens.

**Centre Belge d'Etude de la Corrosion (Cebelcor).** Cebelcor is working on the whole field of corrosion research in close collaboration with other Belgian and foreign organizations.

**Comite International de Thermodynamique et de Cinetique Electrochimiques (Citce).** This organization is continuing its work on the electrochemical characteristics of corrosion.

**Association Vincotte.** The behavior of steam boilers and other pressure engines in Belgium is being checked.

**GERMANY**—G. Schikorr, Chemische Landesuntersuchungsanstalt, Stuttgart.

With substantial cooperation of the Deutsche Gesellschaft für chemisches Apparatewesen (Dechema), the European Corrosion Federation was founded. Its object is to promote the cooperation of European technical and scientific societies working in the field of corrosion. Seven more German societies joined the federation.

Annual conventions or meetings were held by the following societies or their corrosion committees (topics in parentheses):

**Industrial Corrosion Association of Technical and Scientific Societies.** (Organization of cooperative work among the individual corrosion committees)

**German Bunsen Society.** (Electrochemical processes at metallic electrodes)

(Continued on Page 100)

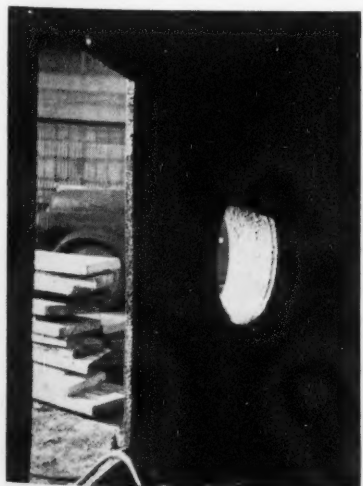


Figure 2—This manhole cut at ground level shows the original thickness of the bottom course plates to be virtually unaffected.

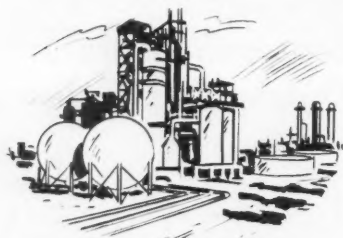


## Foreign Corrosion—

(Continued From Page 99)

**German Metallurgical Society.** (Passivation and attacking mechanisms in the corrosion of metals)

**German Society of Gas and Water Specialists and Society of German Electrical Engineers.** (Exterior corrosion of pipelines and cables)



### STOP COSTLY CORROSION ON REFINERY TANKS AND LINES WITH "CORECO" RECTIFYING SYSTEMS

Experienced "CORECO" engineers, specialists in design and installation of rectifier and galvanic anode cathodic protection systems, are ready to analyze and solve your corrosion problems.

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FOR EFFECTIVE  
CATHODIC PROTECTION

A Complete Design and Installation Service.  
Call, wire or write today to

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**Industrial Galvanizing Committee.** (Hot-dip galvanizing)

**Association of German Chemists.** (Pigments and paints)

**Ship-Building Technical Association.** (Removal of skin on rolled metal; tanker corrosion)

**Anthracite Coal Mining Society.** (Corrosion and corrosion prevention of mine shafts, low-pressure air lines, cold-, warm- and cool-water equipment, condenser tubes, long-time installations)

**German Iron Workers Society.** (Reports on several topics in the field of steel corrosion)

Corrosion committees of the following societies were active in the preparation of general directives or specifications (subjects in parentheses):

**German Committee for Steel Construction.** (Painting of steel structures)

**German Standards Committee—Technical Standards Committee on Material Testing.** (Corrosion measurement, oil testing, atmospheric testing, protection by metallic and non-metallic coatings)

**Association of German Chemists.** (Paints, corrosion by cold and warm water)

**Ship-Building Technical Association.** (Painting of ships and marine structures)

**German Iron Workers Society.** (Painting of steel structures)

**Association of German Engineers.** (Corrosion protection in heating and low-pressure steam installations by water treatment and cathodic protection)

**Central Society of Electro-Technical Industry.** (Corrosion protection of cables)

Almost all of the corrosion committees mentioned conducted research in their field or supported such research. In addition to these the following are mentioned:

**Consultation Center for Sea-Worthy Packaging.** (Corrosion protection during overseas shipment; formation of condensed water in ships)

**German Group of the International Research Association for Water and**

**Sewage, Corrosion Division.** (Alternating current corrosion in the frequency range of 0.05 to 50 Hz)

ITALY—R. Piontelli, Laboratory of Electrochemistry, Physical Chemistry and Metallurgy, Politecnico di Milano

## RESEARCH

**Fundamental**—In the Laboratory of Electrochemistry of the Polytechnic of Milan systematic work has been done on the electrochemical behavior of metals (Sn, Zn, Cd, In, Tl, Pb, Cu, Ag, Au, Ni) as polycrystalline and single crystal anodes and cathodes in different conditions of temperature and composition of the electrolytic solutions. The passivity phenomena of metals also against fused salts have been investigated. A group of papers has been published. These researches are sponsored by the European Office of the Air Research Development Command USAF by contract through the European Office, ARDC, Brussels.

Fundamental research on corrosion has also been carried out in the laboratory of chemistry of the University of Ferrara (Prof. L. Cavallaro).

**Practical**—A large group of industrial problems has been studied in the Milan Laboratory, where G. Bianchi has done systematic work on (by models and electrochemical measures) on the problem of the "protection voltage of iron, underground" and on the salt spray test.

## ORGANIZATION, MEETINGS

The Commission for Corrosion of the National Council for the Research (CNR) held a large number of meetings in which: problems involved in underground corrosion, steel corrosion in concrete and a corrosion glossary and many other topics were discussed (Professor B. Focaccia, in chair; Prof. M. M. Jacopetti, vice-president).

The AIM (Associazione Italiana di Metallurgia) has promoted a Corrosion Center (Prof. L. Cavallaro, in the chair).

A second Symposium on Tin sponsored by Tin Research Institute of London has been held in September in the Laboratory of Electrochemistry of the Polytechnic of Milan. The electrochemistry of tin alloys has been discussed.

JAPAN—T. Fujiwara.

As previously reported there are six corrosion related groups in Japan, namely the Corrosion Committee of the Japan Society for Promotion of Science, the Technical Committee for Prevention of Corrosion, affiliated with the Japan Electrochemical Society; Electric Corrosion Research Committee, affiliated with the Institute of Electrical Engineers of Japan and Electric Corrosion Committees of Tokyo, Kansai and Tokai.

The first three named consist more or less of theoretical or technical groups to investigate and solve the general corrosion problems while the later three named consist of practical groups to control or settle the practical corrosion problems in the field. Featured activities of individuals of the above groups during 1955 are as follows:

(Continued on Page 102)



**APEX** for cathodic protection

**MAGNESIUM ANODES**

Corrosion control for under-ground and under-water pipelines and other metal structures regardless of all other methods used.



APEX Anodes are available in 17 lb. and 32 lb. bare anode with or without wire, or complete packaged anode with wire and back-fill ready for installation.

Anode folders or technical consultation with our engineers available upon request.

**APEX SMELTING COMPANY**

# for CORROSION protection...

25 ppm SARKOSYL® O

200 ppm COMPETITIVE INHIBITOR C

## a different corrosion inhibitor

# SARKOSYL® O

N-oley sarcosine

Test it yourself. Rust a sandblasted 1010 steel panel in synthetic sea water. Immerse wet for one week in gasoline containing 25 to 200 parts per million of SARKOSYL O, then for one week in sea water again; clean and determine weight loss. Compare with any other commercial inhibitor. If you're not convinced, make the test tougher: After removing the panel from the inhibited gasoline, expose to a salt spray for one week; then compare protection with any other commercial inhibitor. Full details on this test procedure are available on request.

On the basis of this and other tests in our laboratories, we can recommend SARKOSYL® O for use in

OIL TANKERS • STORAGE TANKS  
PIPELINES • IN LUBRICANTS  
PRESERVATIVE OILS • GASOLINE  
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"hot lines" and "holidays"  
**GLASFAB**®

EASY TO APPLY — RELIABLE  
HIGH TENSILE STRENGTH

A wholly inorganic, loom woven glass fabric — ideal for handwrapping pipe joints and extensions — Glasfab is non-capillary and adds year to the life of coal-tar, asphalt bitumen, or plastic coatings.

MIDWESTERN  
PIPE LINE PRODUCTS CO.  
Box 1886 Tulsa, Oklahoma

## Foreign Corrosion —

(Continued from Page 100)

The Corrosion Committee of the Japan Society for Promotion of Science has completed preparation of the basic data on the phosphoric acid treatment of metals and the vapor phase corrosion inhibitors for the Standard Specification.

The Kansai Electric Corrosion Control Committee has made an important contribution to standardization of the drainage facilities. Under auspices of the Japan Electrochemical Society (Technical Committee for Prevention of Corrosion), the Chemical Society of Japan and the Corrosion Committee of the Japan Society for Promotion of Science, a corrosion symposium was held on November 1-2, 1955 at Tokyo University for scientists and technical men from all over the nation to discuss the following subjects: Dry corrosion of nonferrous alloys, electrolytic potential affected by the residual strain of metal, relation between the hydrogen overvoltage at  $\epsilon$  phase and the lattice constant of certain nonferrous alloys.

Effect of polarization treatment (pretreatment) upon the rate of corrosion of iron, electrolytic potential in the mechanism of corrosion of metal, determination of the polarization curves to be used for corrosion researches, formation of local galvanic cells due to the segregation of noble metal ions during corrosion of the magnesium, activation energy of the corrosion reaction of magnesium in a mixture of water and methanol.

Study by means of electron diffraction

tion of stress corrosion of 18/8 stainless steel. Cathodic protection of metals in moving sea water, effect of purity of zinc anodes upon cathodic protection of metals.

Paints to be used jointly with cathodically protected metals, corrosion of basis metal painted with various kinds of pigments, solubility of steel in an unhydrated phosphoric acid.

Influence of halogen ions upon an acid resisting properties of stainless steel, corrosion of steel in a sodium chlorate solution, research on the amine series inhibitors, study on the deterioration of organic industrial materials due to oxidation: 1) Rosin and abietic acid, 2) Compounds of paraffin series; effect of surface-active agents on corrosion and protection of metal.

**NEW ZEALAND**—F. J. T. Grigg, Director, Dominion Laboratory, Department of Scientific and Industrial Research, Wellington, New Zealand. **Department of Scientific and Industrial Research Activities**—A long-term underground-corrosion-testing project is in progress. Schwerdtfeger potential measurements have been applied to the evaluation of external casing corrosion on geothermal steam bores. Investigations are in progress on the cathodic protection of geothermal-bore casing.

A project on cathodic protection of a floating-dock hull is in progress. Investigations are continuing in corrosion by geothermal steam, principally stress-corrosion of austenitic stainless steel by the steam and corrosion by underground geothermal waters at about 2000 ft. depth, 250 C. A project on corrosion by aggressive-industrial bore waters is in progress. Work on protective coatings for the prevention of fertilizer corrosion in top-dressing aircraft has been completed.

**UNION OF SOUTH AFRICA**—W. J. Copenhagen, South African Council for Scientific and Industrial Research, Corrosion Unit, Capetown.

The following report is submitted to indicate the activities of the Corrosion Unit (At Cape Town) of the S. A. Council for Scientific and Industrial Research. It is regretted that no report was forwarded in 1955 and this summary of corrosion work covers 1954 and 1955.

Two main projects are in progress: The Atmospheric corrosion of reinforcing steel in concrete structures in marine environments.

Highway bridges on the Natal Coast in the proximity of the sea, are found to suffer from the spalling of minor sections (balusters and handrails) due to the corrosion of the reinforcing steel in a matter of four years. There are also indications that some of the major sections are likely to be involved. A corrosion chemist and a concrete engineer working in close cooperation, are studying the various types of electrochemical cells that may be active, as well as the effect of cement-aggregate, cement-water mixtures and their effect on the permeability of the concrete.

The atmospheric corrosion of galvanized iron.

Exposure racks have been set up at two coastal towns, viz. Cape Town and Durban, and at one inland center, Pretoria.

(Continued on Page 104)



**ARMOR PLATE**  
all types of  
structural steel,  
wire, pipe, fasteners . .  
**AGAINST RUST!**

The Nowery J. Smith Company can give our rusty friend's iron tuxedo a tough zinc coating to seal out corrosion even while dragon-slaying or maiden-rescuing! Whether your galvanizing job is routine—or singular as a suit of armor—call the Nowery J. Smith Co., Underwood 9-1425, for the best in hot-dip galvanizing service.



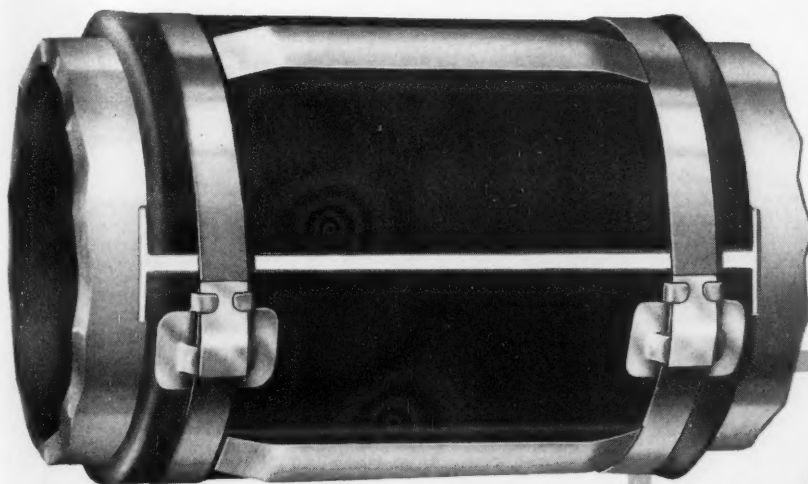
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## *for the tight jobs*



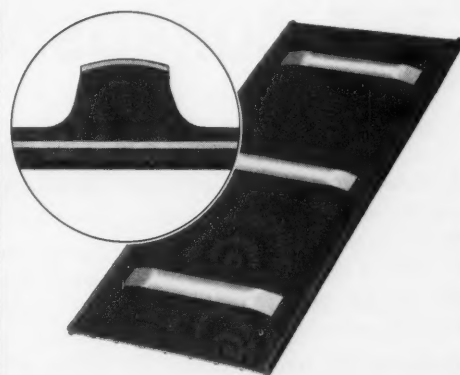
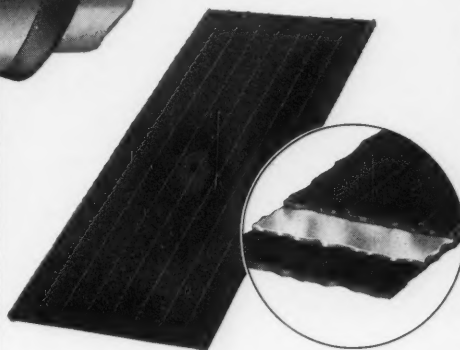
**2" through 12"**

### The "Maloney Model 56" Casing Insulator

Manufactured with Neoprene, which is vulcanized to the steel band core and to the rounded steel runners, there is no place to "short-out" between the casing and the carrier line. The steel core is completely surrounded with Neoprene and is bonded under heat and pressure to give the same strength as on army tank tread blocks.

Shipped flat, the Insulator is easily field formed and banded to the carrier pipe with stainless steel bands. Joint is sealed with a Polyethylene band.

Manufactured in sizes from 2" through 12", it can be used either on installations where there is only one nominal pipe size difference or on installations having a larger differential.



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PRECISION IN RUBBER —  
METAL — PLASTICS**

"Something from the Irishman"

**F. H. MALONEY**  
*Company*

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## Foreign Corrosion—

(Continued From Page 102)

The quantitative estimation of "white rust" after exposure periods of 1, 3, 6, 12, 18 and 24 months is being assessed. The nature of white rust is also investigated.

### Corrosion problems for government departments and industries.

These investigations continue and include the following:—Cathodic protection of steel sheet piling in harbor works, corrosion of telephone lead coaxial cables, corrosion in heat exchangers, metals in the building industries (particularly steel windows at coastal towns) corrosion and cavitation in marine propellers, buried pipelines.

In addition, in conjunction with the S. A. Bureau of Standards, the members of the corrosion unit attend committee meetings on protective paint systems for structural steels, code of practice for surface preparation of steel prior to painting, as well as the advisory sub-committee on corrosion for the Council for Scientific and Industrial Research.

SPAIN—E. Jimeno, Ministry of Marine, Spanish Institute of Oceanography, Madrid.

Our country is expanding its heavy industries in a remarkable way and it is now that, due to this development, the problem of corrosion is being felt intensely, with its sequel of heavy economic losses, as reflected in the returns

of the industrial enterprises. It is for this reason that the big industries are already paying the greatest attention to corrosion. This did not occur before as at that time it only affected smaller industries whose objectives were more limited. The big industrial enterprises now carry out anti-corrosion tests and experiments with metallic materials and with all kinds of anti-corrosive materials. Unfortunately, however, this work is being done in an isolated manner, hence the reason for consideration being given to the establishment of a centre devoted to the study of problems brought about by corrosion. At present only a few experts and scientists publish papers on corrosion. This is the result of their own interest in the matter, so that they do not constitute a team with a fixed aim in view.

It may be mentioned that, in industry, anti-corrosive protection is almost limited to the use of paints, in its full range of varnishes and pigments, in which are used plastic materials and inhibitory or sacrificial pigments.

Conversion finishings, phosphates, chromates and oxalates—particularly the first mentioned—are coming into use. Phosphatizing has been better accepted by the metallurgical industry in stretching, mechanical treatment and extrusion rather than in the anti-corrosive aspect, although it must be said that the motorcar and motor-bicycle industries, which up to now have not used phosphatizing, are going to adapt it in their finishing lines.

Some hydro-electric firms are also using phosphatizing. It is brush-applied direct to electric pylons in order to improve the adherence and life of the paints. To cite an example, phosphatizing is used in the south of Spain with apparent good results by finishing it with a paint containing chlorinated rubber and aluminium. In this area, apart from the problem of corrosion there exists also the problem of abrasion as a result of sand particles blown about in the air and this problem seems to have been mitigated by the firm adherence of chlorinated rubber to the very fine coat of phosphate and also by its elasticity.

There are great problems of sea corrosion. Our tanker fleet is constantly undergoing repairs and many tons of iron have been lost. Up to now the Spanish tanker fleet has not taken any special measures against corrosion with the exception of the painting of the outside of the hulls.

The use of anodes of magnesium or zinc has not become general and very little has been done so far in this aspect. This is perhaps due to the fact that its use may not seem very economical to industrialists for the time being.

## Air Pollution Research

The National Science Foundation has awarded \$13,000 to Carnegie Institute of Technology for studies aimed at diminishing air pollution. Principal investigator will be George Westinghouse, Professor of Engineering, Gaylord W. Penney, who invented the Precipitron, an electronic precipitator. He will investigate electrostatic phenomena related to aerosols.

Corrosion selects information on corrosion work by organizations other than NACE and publishes it monthly.

## NOW...for the first time measure corrosion **DIRECTLY!**



## THE CORROSOMETER\*

*Quick, Convenient, Accurate.* Now you can measure progress of corrosion at any location in your system or plant—without need for handling test coupons, taking samples or disturbing plant operations!

The Corrosometer system consists of any number of probes which remain in continuous service, and a portable meter which simply plugs into each probe to indicate extent of corrosion directly in micro-inches of metal lost.

Corrosion measured takes place on the specimen built into the probe.

Probes are available in many different constructional alloys to meet various processing requirements and systems in chemical plants, food plants, refineries—wherever corrosion is a problem. *To get the facts on how to boost corrosion control efficiency and cut your costs with the Corrosometer, write direct today for full details!*

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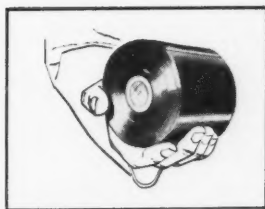


## "SCOTCHRAP" raises pipe-to-soil potential

Wondering what to do about a low pipe-to-soil potential? Better think about "Scotchrap" Pipe Insulation Tape. It may be the easy way to solve the problem—at the lowest possible cost in the long run.

For example, engineers of a major pipeline company recently checked the pipe-to-soil potential at each valve setting on a 30-inch main. Average reading: 0.65-0.75. Two new rectifiers at the worst trouble spots would cost \$4000.

They decided to put "Scotchrap" Brand



WIDE WIDTHS of "Scotchrap" give fast coverage.

Pipe Insulation Tape to work instead. They wrapped 4 feet of the 30-inch line at every valve—two feet above the ground, two feet below. They also wrapped about 20 feet of bare line where the coating crew had stopped short.

The result? Pipe-to-soil readings in the most trouble-some areas now average 0.80-1.1 volts with the same rectifier capacity. **Net saving: \$1500!**

Try "Scotchrap"! See for yourself! Write for free booklet "Scotch" Brand Products for Pipeline Protection" Dept. BQ-76.

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**SCOTCHRAP** Pipe Insulation Tape  
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## Program for First Appalachian Corrosion Short Course at Morgantown, W. Va. Given

The program for the First Annual Appalachian Underground Corrosion Short Course held June 11-13 at West Virginia University, Morgantown is listed in part as follows:

### Monday, June 11

2-5 pm—Fundamentals of Corrosion, W. A. Koehler and Staff, followed by Inco motion picture "Corrosion in Action."

### Tuesday, June 12

#### Class Period 1, 9 to 9:50 am

A Demonstration of the Theory of Cathodic Protection, W. L. Kretschmer, Columbia Gas System Service Corp.

Test Methods Used by Manufacturers in Determining Coating Specifications, C. L. Dey, Koppers Co. Inc.

Magnesium Anode Installation, I. E. Davis, The Ohio Fuel Gas Co.

Corrosion Consideration in New Telephone Cable Construction, J. E. Keskinen, Bell Telephone Co. of Pennsylvania.

Electrolysis Reverse Current Switches, R. M. Keller, Atlantic Pipe Line Co.

#### Class Period 2, 10-10:50 am

Fundamental Analysis of Stray Current Corrosion, Percy Hort, Atlantic Pipe Line Co.

Field Application of Hot Applied Coating, James Romeis, Perrault Equipment Co.

Specifications for Expendable Anodes, Burke Douglas, The Dow Chemical Co.

Field Corrosion Survey of Power Cables, R. L. Smith, Duquesne Light Co.

Plastic Piping for Underground Service, L. S. VanDelinder, Carbide and Carbon Chemicals Co.

#### Class Period 3, 11-11:50 am

Fundamental Field Practices Associated with Electrical Measurements, L. H. West, The Standard Oil Co. (Ohio).

Glass Fiber as a Reinforcement for Pipe Line Enamels, H. W. Paul, L-O-F Glass Fibers Co.

Design and Backfill for Magnesium Anodes, Burke Douglas, The Dow Chemical Co.

Corrosion Testing of Lead Cables in Non-Stray Current Areas, J. M. Fouts, New York Telephone Co.

Literature-Survey of Well Casing Corrosion, R. H. Edele, West Virginia University.

#### Class Period 4, 2-2:50 pm

A Practical Demonstration of Corrosion Instruments, J. G. Keener, The Manufacturers Light and Heat Co.

Coal Tar Coatings for Protection of Underground Structures, N. T. Shideler, Pittsburgh Coke and Chemical Co.

Consideration When Designing a Distribution System, S. C. Jones, Cincinnati Gas and Electric Co.

Mine Acid—A Corrosive Agent, S. A. Braley, Mellon Institute.

High Voltage Testing of Pipe Line Coatings, M. W. Belson, D. E. Stearns Co.

#### Class Period 5, 3-3:50 pm

Coatings Fundamentals, J. A. Schauer, Atlantic Pipe Line Co.

Factory Coating and Wrapping of Steel Pipe, F. C. Yeazel, Pipe Line Service Corp.

Electrolysis Currents Related to a Distribution System, C. M. Rutter, Equitable Gas Co.

Control of Corrosion in Water Mains, Wallace Grant, W. Va. Water Service.

Epoxy Resins for the Corrosion Engineer, T. J. Skotnicki, Minnesota Mining and Manufacturing Co.

#### Class Period 6, 4-4:50 pm

Rectifier Fundamentals for Service Men, E. L. Newmyer, Good-All Electric Mfg. Co.

Waxes, J. G. Surcek, Dearborn Chemical Co.

Protection of Services, P. P. Skule, The East Ohio Gas Co.

Greater Than Gold—A Movie, C. L. Dey, The Koppers Co. Inc.

Zinc Controls Corrosion, 35-minute motion picture, American Zinc Institute

### Wednesday, June 13

#### Class Period 7, 9-9:50 am

Expendable Anode Fundamentals, E. C. Reichard, American Smelting and Refining Co.

Cold Applied Coatings, J. H. Royston, Royston Laboratories, Inc.

Survey for and Design of Rectifier Ground Beds, H. Byrns, Columbia Gas System Service Corp.

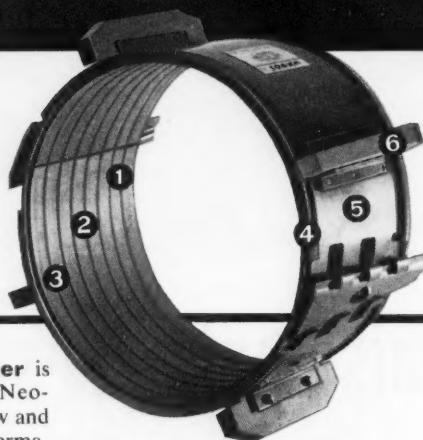
Design of a Coal Mine Drain, Anthony Amurgis, The Manufacturers Light and Heat Co.

Corrosion and Cathodic Protection Testing Instruments, M. C. Miller, manufacturer.

(Continued on Page 108)

## Plico Insulating Spacers assure lowest permanent cost!

When you compare spacer values, look for the spacers that combine lower primary cost and reduced pipeline cathodic protection maintenance cost to give you lowest overall cost. Feature for feature, superior Plico Insulating Spacers are your best buy.



**1 One-piece extruded liner** is made of 100% virgin duPont Neoprene. High resistance to cold flow and high dielectric strength assure permanent protection to carrier line.

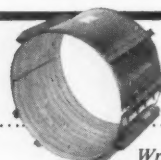
**2 No center gaps** or split liners to permit coating displacement or leakage of current to metal portions of spacer.

**3 Multiple longitudinal ribs\*** act as a gripping tread, prevent slippage during installation and frictional displacement of coating (cold flow) after installation.

**4 Extruded liner lips** prevent movement of liner on heavy gauge steel band.

**5 Rugged construction** to withstand installation shock loads and post-installation static load. Plico Spacer bands are cold-formed of 12-gauge steel in 12" diameter and larger, and of 14-gauge steel in 10" diameter and smaller. Band widths are 6", 8" and 12".

**6 Skids of heavy-duty**, high-density laminated Micarta, accurately spaced and securely fastened to the band, provide high dielectric strength and abrasion resistance and assure the extra safety factor of double insulation.



Illustrated above is the Plico Type 506WM spacer, with wedge for speedy and positive closure. Bolt-closure is also available as shown at left (Type 512M).

\*Patents Pending



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PIPELINE COATING & ENGINEERING CO., INC.  
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# NEW NATIONAL

TRADE MARK

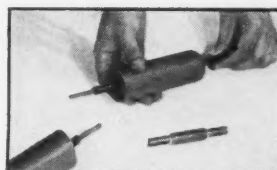
## ANODE—TYPE QA\* OF LONG LASTING NA GRAPHITE

...LOW IN COST

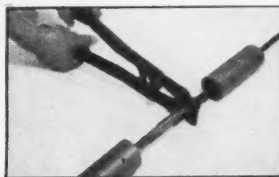
...EASY TO USE

...WIDE APPLICABILITY

### ASSEMBLING TYPE QA ANODES



Cut and strip cable; slip on anode halves



Crimp connector to cable ends



Join anode halves, using sealing cement

■ With the assembly technique shown above, long-lasting anodes of National Carbon's NA graphite can be installed on cable *exactly where they're needed*. Type

QA Anodes are shipped from stock in three standard sizes: 2" x 12", 2" x 20" and 3" x 30". Crimp-type connectors fit sizes 4, 6 or 8, 7-strand cable.

#### Use them for protecting —

- BARE PIPE • WATER TANKS • METALLIC CABLE SHEATH • SUBMERGED STRUCTURES

In many applications, you'll find "National" Anodes — Type QA the most

economical for construction of conventional, horizontal or vertical ground beds.

### FIGURE YOUR NEXT JOB WITH TYPE QA ANODES AND SAVE!

#### WRITE FOR CATALOG SECTION S-6525

The term "National" is a registered trade-mark of Union Carbide and Carbon Corporation

**NATIONAL CARBON COMPANY** • A Division of Union Carbide and Carbon Corporation, 30 East 42nd St., New York 17, N. Y.

Sales Offices: Atlanta, Chicago, Dallas, Kansas City, Los Angeles, New York, Pittsburgh, San Francisco

IN CANADA: Union Carbide Canada Limited, Toronto

\*Patents Applied For

## North Dakota State College Short Course Scheduled

A 5-day short course on maintenance coatings will be given July 30-August 4 inclusive on the campus of North Dakota State College, Fargo, N. Dak. The course, titled "Maintenance Coatings Short Course," the second held by the college, will be at the school's Student Memorial Union Building.

Nine lecturers are scheduled to participate under the direction of Wouter Bosch, teacher of extra-curricular paint courses at the school since 1947. Registration fee of \$25 is payable in advance to School of Chemical Technology, North Dakota State College. Students will be housed in Ceres Hall Dormitory on the campus for \$14, to be paid after arrival.

Breakfast and luncheon will be served on the campus.

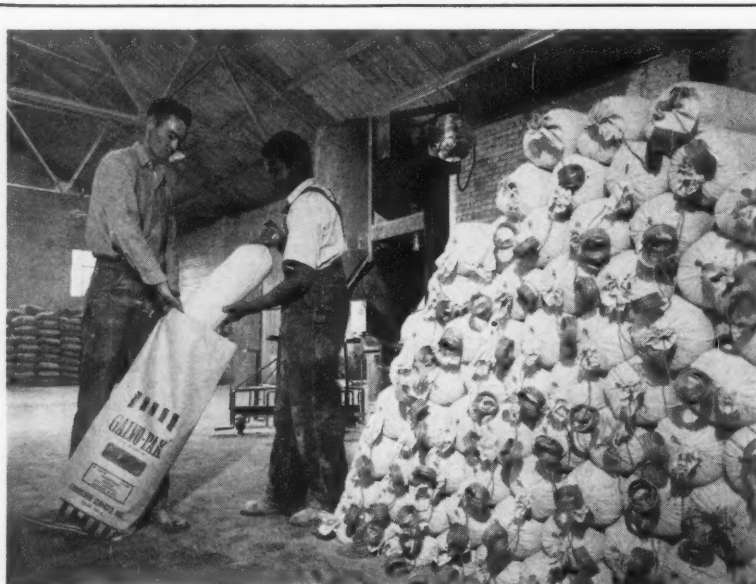
Some of the items on the program are: Selection and Use of Maintenance Coatings, John W. Nee, Briner Paint Mfg. Co., Corpus Christi, Texas.

The Nature of Corrosion, Wouter Bosch. A 2000-Acre Paint Job, Frank A. Harrison, Dow Chemical Co., Midland, Mich.

Cost Studies of Refinery Maintenance, R. S. Freeman, Cities Service Refining Corp., Lake Charles, La.

Making the Most of the Spray Painting Method, Irvin B. Thomas, The DeVilbiss Co., Toledo.

Subscribers to NACE's Abstract Card Service receive cross-indexed abstracts of most of the available literature on corrosion.



## ARE YOU GETTING WHAT YOU PAY FOR?

The exacting standards CSI engineers have set for themselves are your guarantee of your money's worth.

When you buy magnesium anodes—either bare or packaged—from CSI, you get exact weight, plus or minus only the accepted three per cent. You also get the metal composition you specify. All CSI anodes are just as represented.

CSI regularly stocks magnesium anodes in many different sizes, shapes and metal compositions to meet your needs. Included are Dow's new high-potential Galvomag anodes. CSI also offers a complete line of other name-brand cathodic protection materials, plus expert consulting and installation services.

Call or write today for estimates or competitive quotations. Ask for a free copy of the latest CSI report on the subject, "What size and shape of anode would be best on your job?"

**CSI**

**CORROSION SERVICES  
INCORPORATED**

Tulsa, Oklahoma

P. O. Box 7343, Dept. G6

Telephone: Circle 5-1351

## BOOK REVIEWS

**The Practice of Anodic Oxidation of Aluminum.** (In German.) 355 pages, 6 x 8 7/8 inches, cloth. 1956. W. W. Hubner and A. Schiltknecht. Aluminum—Verlag GmbH, Düsseldorf, Per copy, DM 19.60.

A handbook giving very complete information about the materials, processes and materials related to anodic oxidation of aluminum. Included are flow charts, examples of plant layouts, instructions on instrumentation, illustrations of techniques successfully employed, jigs, types of equipment and tabulated data on the characteristics of coatings produced on various types of aluminum alloys. There is a list of literature references, an alphabetical subject index, an alphabetical list of plants handling aluminum for conversion coatings and a section devoted to advertising of German firms producing aluminum materials and shapes.

## New York University Titanium Lectures Set

The second annual titanium lecture program for practicing engineers will be conducted at the New York University College of Engineering September 10-14. Twenty-five lectures will be presented covering extraction and melting, phase diagram metallography and alloying, heat treatment and mechanical properties, mechanical metallurgy and applications and fabrication.

Attendance will be limited. Registrations will be accepted until August 15 by Harold Margolin, New York University College of Engineering, University Heights 53, N. Y.

## Program for First—

(Continued From Page 106)

**Class Period 8, 10-10:50 am**

Corrosion Control Incorporated Into Pipe Line Construction, W. R. Curley, Stuart Steel Protection Corp.

Protective Tape Coatings, H. D. Segool, Polyken Products.

The Installation of Ground Beds and Rectifiers, H. H. Hull, The Ohio Fuel Gas Co.

Corrosion Problems from a Practical Fundamental Standpoint, V. V. Kendall, National Tube Division, U. S. Steel.

Some Considerations in Coating Evaluations, H. C. O'Brien, Jr., Royston Laboratories, Inc.

**Class Period 9, 11-11:50 am**

Corrosion Inspectors, G. F. Orr, United Fuel Gas Co.

Asphalts, J. G. Surcheck, Dearborn Chemical Co.

Cathodic Protection Interference, S. J. Bellasai, Transcontinental Gas Pipe Line Corp.

Diagnosis of a Corrosion Problem, V. V. Kendall, National Tube Division, U. S. Steel.

Initiating a Corrosion Control Program, F. W. Ringer, Narberth, Pa.

## Solvent Loss Controls

The Air Pollution Control District of Los Angeles contemplates controls and regulations to reduce the evaporation of solvents into the air from painting and cleaning operations.



## NBS Metallurgical Division Corrosion Topics Are Listed

Among the items on the Metallurgy Division Conference at the National Bureau of Standards, Washington, D. C. on May 14 were:

Corrosion of Single Metallic Crystals, J. Kruger.

Corrosion Section: Fundamental Reactions at Metal Surfaces, Kruger, Faris; Corrosion of Aircraft Alloys, Reinhardt, Gerhold; Corrosion of Monocrystalline Metals: Salt Spray Test, T. H. Orem; Stress Corrosion, Logan, Rait; Galvanic Corrosion, W. J. Schwerdtfeger; Underground Corrosion, M. Romanoff.

## Noted Brazilian Engineer, Edison Passos, Succumbs

Edison Passos, a renowned Brazilian engineer who died at Rio de Janeiro was the subject of a special issue of the Brazilian Magazine "Revista do Clube de Engenharia." The issue commemorated the accomplishments of Passos, born November 19, 1893 at Minas Gerais. Numerous engineering works in Brazil were under his direction and he was among other things four times a president of the Engineering Club.

## Czechoslovaks Issue New Industrial Periodical

"Czechoslovak Heavy Industry," an English language, illustrated monthly magazine is now available. Editions are published also in French, German, Russian and Spanish. Yearly subscription rate is \$6 or 50c per copy, payable to Czechoslovak State Bank. The magazine is published in Prague.

The first issue includes technical articles on metallurgy, concrete reinforcing steel, hydraulic presses, welding, investment casting and design.

## Corrosion of Aluminum Cooling Systems Surveyed

"Corrosion in Engine Cooling Systems Containing Aluminum: A literature Survey," by Mildred Benton, Naval Research Laboratory, July 1955 can be obtained from OTC, U. S. Dept of Commerce, Washington 25, D. C. for \$1 a copy. It covers the literature on corrosion in systems including aluminum for 1926 through June 1955.

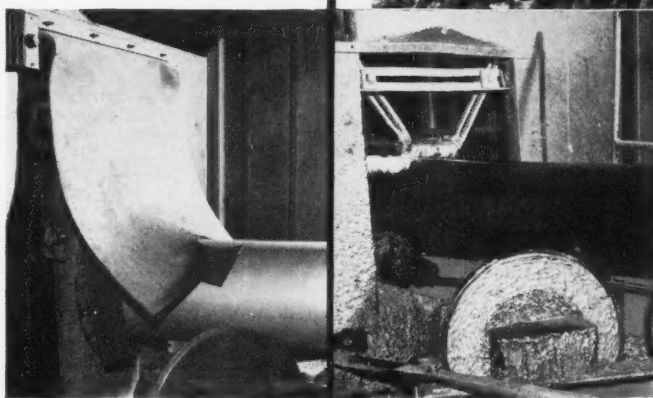
## Tappi Plastics Paper Session

The 11th National Tappi Plastics Paper Conference will be held Oct. 3-4 at the Institute of Paper Chemistry, Appleton, Wis. T. A. Howells of the institute will be general chairman.

## Protective Packaging

The 11th Annual Protective Packaging and Materials Handling Expositions will be held Oct. 21-24 in St. Louis. There will be a concurrent short course at the Kiel Auditorium where the exposition also will be held.

# YOU CAN JEEP ENAMEL BUT NOT ITS BOND



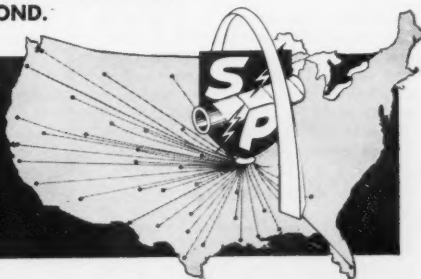
WARM PIPE LEAVING WHEELABRATOR AND PRIMING BOOTH  
IN TEMPERATURE CONTROLLED ROOM.

In SPI's plant, all moisture, rust and scale is removed from your pipe by warming and steel grit cleaning in temperature controlled rooms. The primer is applied immediately to seal out all dirt, dust and moisture. The steel grit cleaned surface of the clean, dry pipe, made up of many tiny facets, provides ideal and long lasting bond of the enamel to the pipe.

Field conditions prohibit such exacting procedures. Wire brushing does not produce the many tiny facets needed to provide ideal bond. Moisture may condense on cold pipe and dirt and dust carried by the wind may collect on it before the primer is applied. When the pipe is jeeped, this dirt and moisture may not show up as holidays, but later, when field c/w pipe is underground, costly holidays may result because of poor bond.

**REMEMBER, YOU CAN JEEP ENAMEL BUT  
YOU CAN'T JEEP ITS BOND.**

THROUGH  
FREIGHT  
RATES AT  
THE ST. LOUIS  
GATEWAY



**standard pipeprotection inc.**

3000 SOUTH BRENTWOOD BLVD. • ST. LOUIS 17, MISSOURI

## Equipment Services

# NEW PRODUCTS

## Materials Literature

**Phenoline 35**, a modified phenolic two-coat heavy duty maintenance system providing a 12 mil film thickness, is catalytically set. The material, with 86 percent solids, gives a dense, non-porous film according to manufacturers, Carboline Co., 331 Thornton Ave., St. Louis 19, Mo. Coverage is 200 square feet per gallon and the resulting coating is resistant to splash, spillage and fumes of most acids, alkalis and solvents. It can be applied over sandblasted or wire-brushed steel and also is recommended for ceilings and concrete floors.

**DeVilbiss Company**, 300 Phillips Ave., Toledo 1, Ohio, reports development of a pump exclusively for handling of paint. Designated P-QBF, it is made in several models to handle materials directly from a 55-gallon drum. One model is built with a 10-gallon hinged lid tank.

**Carpenter PVC**, a 6-page folder available from Carpenter Steel Co., Alloy Tube Div., Union, N. J., describes the company's polyvinyl chloride pipe and fittings. Data are given on physical properties, maximum working pressures, calculated bursting pressures and other criteria.

**Tetrafluoroethylene** woven into fabric now is being used under heavy load to face metal suspension joints. The joints

so faced operate without lubrication with a reduction in friction loss by more than 50 percent over standard lubricated suspension joints used in automobiles. American Fiber Products Co., Detroit developed this use for duPont's Teflon material. Permanently lubricated sealed ball and socket joints are being fabricated using the new material at no cost over standard joints.

**Dekoron Instrument** tubing made by Dekoron Products Div., Samuel Moore & Co., Mantua, Ohio, is described in Bulletin 546. Numerous types of plastic coated metal tubing in single or multiple harness are described.

**Vanadium Corp.**, of America will build near New Alexandria, Jefferson County, Ohio, a new plant for the production of ferro alloys, principally ferrocromium.

**Michigan Pipe Co.**, 2415 Burdette Ave., Ferndale, Mich., has been named exclusive distributor in the United States and Canada for Bart Electro-Clad nickel plated pipe and fittings. Manufacturing will be centralized in a new plant in North Newark, N. J. By the Bart process, pore-free nickel plating also can be applied to sheet and plates, which are being marketed exclusively by Colorado Fuel and Iron Corp.

**Plastisols** can be applied in an "in plant" unit available from Quelcor, Inc., Chester, Pa. The company undertakes to supply a properly compounded polyvinyl chloride plastisol, complete application equipment and thorough training of personnel and application data. Application of the system formerly has been complicated by the necessity of sending items to be coated to the Chester plant of Quelcor. The company believes this new system will permit companies to select and apply themselves plastisols necessary for the protection of their equipment.

**Aminco-Winslow Porosimeter**, a mercury intrusion meter for determination of pore structure has been developed by American Instrument Co., Inc., Silver Spring, Md. Described in Bulletin 2282, the instrument is said to be devoid of operational hazards.

**Unitrace** junctions can be made easier through use of a special cast flange developed by Aluminum Company of America.

**Chemical Milling** of steel and titanium at a pilot plant operated by Turco Products in Los Angeles is being used to train personnel of sub-licensees of the Chem-Mill Process. The pilot line also is being used to form prototype parts for prospective users of the process and as a research center for development of new techniques.

**Glass Cloth** tape bonded to valves and pipe by epoxy resins is being used at the South Charleston, W. Va. plant of Carbide and Carbon Chemicals Co. to protect Duriron pipe carrying alcohol and strong sulfuric acid at 70 to 100 C.

**Coatings and Fiberglass** Research Co., 5000 District Blvd., Los Angeles has

been formed by L. J. Morris and F. C. Lombardo, to provide a specialized consulting service for paint and plastic manufacturers and users. The partners formerly were with Amercoat Corp.

**Electricity** may be produced directly from fission heat in a cell developed at Cambridge University, England. The cell containing hydrogen, oxygen, potassium hydroxide and sintered nickel electrodes produces electricity by reaction of the hydrogen and oxygen under high pressure, according to Isotope Newsletter, Buffalo, N. Y.

**Corrosion Resistance** of titanium is given in a bulletin "Designing Away Corrosion With Titanium" available from Mallory-Sharon Titanium Corp., Niles, Ohio.

**Atlas Mineral Products Co.**, Mertztown, Pa. has designated Ballagh & Thrall, Inc., 1010 Schaff Bldg., 1505 Race St., Philadelphia 2, Pa. as export managers of its products to all countries except Mexico and the United Kingdom.

**Robeson-Preservo Co.**, Port Huron, Mich. has developed a silicone based paint which, applied by spray, dries to a tough finish with high gloss. Intended for use on aircraft, the finish retains its original shine after prolonged exposure to weather and does not chalk or become brittle. Tests have shown the fin-

(Continued on Page 112)

## CERTIFICATES of MEMBERSHIP in NACE

Certificates of membership in the National Association of Corrosion Engineers will be issued on request at \$2 each, remittance in advance. The certificates, which measure 5½ x 8½ inches, are signed by the president and executive secretary of the association.

## CERTIFICATES for PAST CHAIRMEN of REGIONS and SECTIONS

Certificates measuring 9 x 12 inches in size, prepared from an engraved plate, are available for issuance to regional and sectional chairmen. They will be supplied on request of the region or section at \$7.50 each to be paid by the region or section, the cost to be classified as a non-reimbursable expenditure.

Address Orders to

A. B. Campbell, Executive Secretary

NATIONAL ASSOCIATION OF  
CORROSION ENGINEERS

1061 M & M Bldg., Houston 2, Texas

## Lapel Pins



Approx.  
Size

Approximately 7/16 inches high,  
gold, inlaid with bright red  
enamel background to "NACE"  
and deep blue enamel back-  
ground to words "CORROSION  
CONTROL." Ruby center.

For Association Members Only

**\$10**

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## CORROSION PREVENTED with SOLVAY SODIUM NITRITE

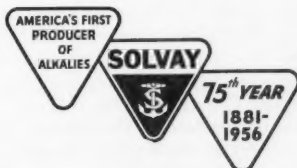
With a low and *economical* concentration of Solvay® Sodium Nitrite you can prevent corrosion in circulating water systems, on metal parts in process and on raw sheets, tubes or bars in storage. The corrosive attack on the pipe at the left, above, is the result of plain water. The pipe on the right was subjected to identical conditions except that the water contained 500 ppm of sodium nitrite.

Solvay Sodium Nitrite works to halt or prevent corrosion by forming an invisible oxide coating on metal surfaces. It is effective with iron and steel and has been reported to suppress the degradation of aluminum, tin, monel, copper and brass. It is non-toxic in the concentrations normally

used to prevent corrosion.

Our booklet, "Sodium Nitrite for Rust and Corrosion Prevention," gives details on how sodium nitrite, alone or in combination with other materials, prevents corrosion in a wide variety of applications. Write for your free\* copy today.

\*In western hemisphere countries only.



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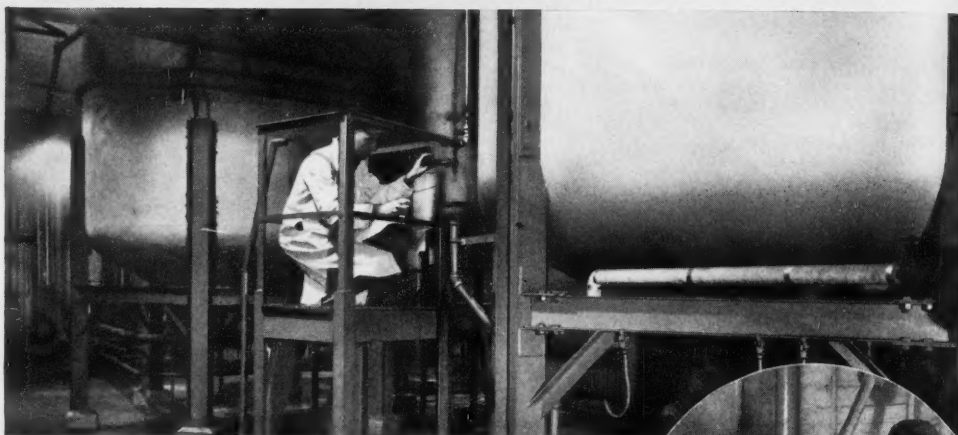
BRANCH SALES OFFICES:

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Soda Ash • Snowflake® Crystals • Potassium Carbonate • Calcium Chloride • Ammonium Bicarbonate • Sodium Bicarbonate • Cleaning Compounds  
Caustic Potash • Sodium Nitrite • Chlorine • Caustic Soda • Ammonium Chloride • Para-dichlorobenzene • Methyl Chloride • Ortho-dichlorobenzene  
Monochlorobenzene • Carbon Tetrachloride • Chloroform • Methylene Chloride • Hydrogen Peroxide



# EPON<sup>®</sup> RESIN does it!



**Paint job still sound  
after four years of  
100% humidity, high temperature  
... in antibiotics plant**



All surfaces, except stainless steel, are protected by Epon resin-based paint formulated by David E. Long Corp., New York 17, N.Y.

## HERE'S HOW...

**P**AINT LEADS A HARD LIFE in the steamy antibiotics plant of the New York Quinine and Chemical Works. Day in and day out, paint endures live steam and high temperatures. The coating on the processing equipment is exposed to hydrochloric acid and caustic soda. All surfaces take frequent hosing and scrubbing.

No ordinary paint would stand up to such usage. Epon resin-based coatings were applied in the Spring of 1952 throughout the plant . . . on walls and ceilings, on all metal piping except stainless steel, on all processing equipment. This Epon resin ester paint, dried at room temperatures, has given complete resistance to cor-

rosion by chemicals and moisture, excellent adhesion to metals, plaster and concrete, and because of its glossy finish has reduced dust settling.

*Four years after it was brushed on, the Epon resin paint looks sound and new. And the Chief Engineer has no intention of repainting this year!*

If you have a paint maintenance problem . . . where ordinary paints just can't take it—ask your paint supplier for Epon resin-based paint. You'll find that it is unsurpassed as an all-purpose industrial coating! Call on Shell Chemical sales offices for names of suppliers. Write for the full Epon resin coatings story, "Planning to Paint a Pyramid?"

*Epon resins are the epoxy polymers made exclusively by Shell Chemical Corporation.*



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CORPORATION**

**CHEMICAL  
SALES DIVISION**

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San Francisco • St. Louis**

**IN CANADA**

**Chemical Division, Shell Oil  
Company of Canada, Limited  
Toronto • Montreal • Vancouver**

## NEW PRODUCTS

(Continued From Page 110)

ish to be virtually unchanged after more than a year's service on an airplane. The finish is recommended as a means of reducing the cost of washing and waxing aircraft, which may be as much as \$120.

**Masland Dural leather Co.**, Amber and Willard St., Philadelphia 34, Pa. will supply rigid vinyl sheets of many types up to 54 by 120 inches at various thicknesses. All materials will be laminated and stress relieved.

**Lo-Flo**, a gasket material made of Teflon and inert fillers is being produced by Balfor Industries Packing Div., 1815 Webster Ave., Bronx 57, N. Y. Improved performance over pure Teflon is claimed with bolt loads of only 52 percent required because of its surface finish.

**Napko Corp.** is now in its new quarters, 5300 Sunrise St., Houston 21, Texas.

**Superior Tube Nickel** and **Nickel Alloy Tubing**, a 20-page catalog, is available from Superior Tube Co., 1729 Germantown Ave., Norristown, Pa. Specific mechanical properties and chemical compositions of 13 analyses of nickel and alloy tubing.

**Ramascar, Inc.**, Milam, Italy will import Carboline Company products for sale in Europe.

**Immunol**, a neutral, non-toxic, non-flammable solvent designed to clean, degrease and rustproof metal surfaces in one operation is available from Harry Miller Corp., 4th and Bristol St., Philadelphia 40, Pa. Mixed with hot or cold tap water, the firm claims it is superior to standard degreasing and cleaning solutions and leaves a protective coating on metals.

**Wrought Iron Pipe for Modern Buildings**, an illustrated 14-page booklet available from A. M. Byers Co., Pittsburgh, Pa., identifies wrought iron pipe and covers its rust resistance, method of fabrication, jointing and other details.

**Land Suction Pyrometer**, developed by Fielden Instrument Div., Robertshaw-Fulton Controls Co., 2920 North Fourth St., Philadelphia 33, Pa. is designed to measure temperatures of gases in difficult situations between 0 and 2900 F.

**Rigid Unplasticized Polyvinyl chloride** pipe, valves and fittings available from Peter A. Frasse & Co., Inc. 17 Grand St., New York 13, N. Y., are described in an 8-page engineering memorandum available from the company.

**Clemcutina, Ltd.**, 2277 Jerrold Ave., San Francisco 24, Cal. is offering a sand-blasting machine capable of supplying two nozzles. The Clemco Continuous Action Machine, Model CA 2460 is a double chamber type holding 1000 pounds of sand with automatic pop-up filling valves and 1 1/4 inch piping.

**Petroleo Brasileiro S. A.** has contracted with M. W. Kellogg Co. to expand its Mataripe refinery from its present 5000 barrel a day capacity to 37,000 barrels a day.

**American Viscose Corp.** plans to expand its research and development facilities at Marcis Hook, Pa. to 220,000 square feet.

**Cooper Alloy Corp.** will expand its facilities at its Hillside and Clark Township, N. J. plants.

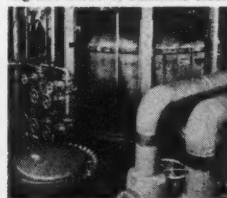
**Lawrence Pumps, Inc.**, Lawrence, Mass. has designed a pump using "G" nickel alloy in the elbow, propeller, water ring, end cap, glands, shaft and casing rated at 2200 gpm. The pump is designed to handle caustic. One of the pumps used over a year to handle a mixture of potassium and sodium hydroxides with carbonates and some organic impurities has required no attention except packing maintenance.

**Perchloryl Fluoride** will be produced in commercial quantities by Pennsylvania Salt Manufacturing Company. This will be the first commercial production of this material, a powerful oxidizing agent, discovered in 1952. It is a colorless gas with characteristic sweetish odor. On cooling it forms a colorless liquid which solidifies at -146 C to a white crystalline solid. When stored in an ordinary cylinder at 70 F the liquefied gas exerts a pressure of only 144 lb. Although thermally stable when heated to the softening point of glass, it will support combustion as readily as pure oxygen.

The DEL coating used in the centrifuge area withstands one hosing down every shift.

DEL Protective Coating is used on processing vessels and piping not made of stainless steel.

Despite constant exposure to live steam, this tank shows no wear. It is protected with DEL.



### All-purpose

## DEL protective coatings

# resist heat, humidity, chemicals and frequent scrubblings

minimize maintenance painting at New York Quinine & Chemical Co., Newark, N.J.

Few conditions are as hard on a paint as those found in an antibiotics plant.

At New York Quinine & Chemical Company, Newark, N. J., geysers of live steam from pilot vents constantly keep plant temperatures high, humidity close to 100%! Installations are unavoidably exposed to hydrochloric acid, caustic soda and other processing chemicals' fumes. In addition, the need for absolute cleanliness demands that floors and process vessels be hosed down regularly to prevent bacterial growth.

To meet these trying conditions, DEL Protective Coatings are used. Today, after 4 years' exposure to heat, humidity, chemicals and daily scrubblings, DEL Protective Coatings have helped keep New York Quinine's plant in excellent shape; very little maintenance painting is needed.

DEL products can solve your protective coating and sealing problems too.

DEL Protective Coatings are ideal where exceptional chemical resistance is a must! You'll find a DEL coating especially designed for protecting metal, masonry or wood against acids, alkalis, alcohol, oil, gasoline, solvents, salts or water. DEL Protective Coatings are formulated for use on new construction as well as plant maintenance, processing equipment and products finishing. There are DEL coatings for interior and exterior uses; many come in a variety of pastel colors.

## FREE!

Get the full story of DEL's many years of in-the-field experience in major chemical processing and industrial plants... Find out how DEL vinyl, epoxy, acrylic, silicone, synthetic rubber protective coatings and DEL Synthetic Rubber Compound (for sealing, caulking and glazing) can help you. For free literature, write today!



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C-77

Gentlemen: Please send me free literature on DEL Protective Coatings and DEL Synthetic Rubber Compound.

My name \_\_\_\_\_ Title \_\_\_\_\_

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City \_\_\_\_\_ Zone \_\_\_\_\_ State \_\_\_\_\_

## MEN in the NEWS

**H. D. McLeese** has been elected a vice-president of Metal & Thermit Corp. He is general salesmanager.

**H. M. Harper, Jr.** has been made secretary of H. M. Harper Co., Morton Grove, Ill.

**Robert W. Buzzard**, a project leader in the Metallurgy Division of the National Bureau of Standards died of a heart attack while attending a conference at Ames, Iowa May 3. He worked for many years on the development of anodic coatings for aluminum and magnesium alloys.

**Maxwell D. Millard** has been made general salesmanager of American Steel and Wire Div., United States Steel Corp.

**Phillip L. Williams** has been appointed manager of Reinforced Plastics Engineering Development for Owens-Corning Fiberglas Corp., Toledo 1, Ohio. John S. McBride has been named Technical Manager, Plastic Reinforcement Laboratory.

**James S. Crowl** has been named supervisor of process research by Acheson Colloids Company, Port Huron, Mich.

**Maurice F. Garwood**, chief materials engineer for the Chrysler Corp. has been awarded the professional degree of Metallurgical Engineer at Ohio State

University in recognition of engineering ability and accomplishments of a high order.

**Leonard W. Kates** is now manager of commercial development for the Atomic Energy Division, Sylvania Electric Products, Inc.

**Glenn E. Seidel** has been appointed to the newly created corporate position of vice-president in charge of engineering for Minneapolis-Honeywell Regulator Co. He will coordinate at the management level research and engineering activities of the corporation.

**Frederick A. Gilbert** has been elected president of Becco Chemical Division, Food Machinery & Chemical Corp.

**Thomas M. Nourse** has been appointed Pittsburgh district sales manager for Hagan Corp.

**Montgary Explorations, Ltd.**, Winnipeg, Canada has taken control of Alox Corp., Niagara Falls, N. Y. James E. Shields, associated with Alox for 20 years, has been elected president. Clarence A. Weltman has been made technical director in charge of operations.

**James R. Ervin** is the new vice-president and sales manager of the Kennedy Valve Mfg. Co.

**W. B. Brooks** is now senior metallurgist in the Dow Texas Division Electrochemical Engineering Department. He joined Dow in 1948 and is a member of ASM and NACE.

**Richard R. Burlingame**, a chemical engineer in the central research division of Cargill, Inc., has been awarded the American Institute of Metallurgical Engineers' 1956 Journal of Metals Award for the most outstanding paper presented at the organization's annual meeting.

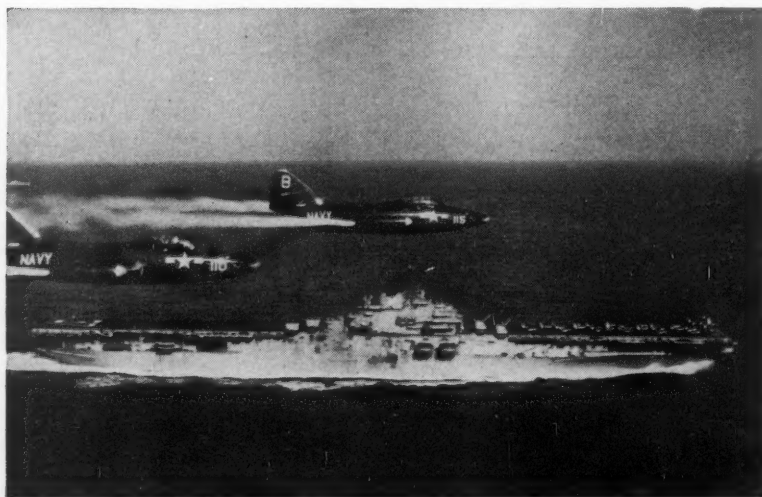
**Leslie A. Gillette** will be responsible for the activities of the chemical and chemical engineering sections of the River-view, Mich. plant of Sharples Chemical Division. He is the new manager of its technical department.

**George Orr** has been appointed Southeastern district salesmanager for Hill, Hubbell & Co., Division of General Paint Corp. His headquarters will be at Charleston, W. Va.

**E. Wayne Haley** is new assistant to the president of Columbia-Southern Chemical Corp. He also has been elected a vice-president and director of Pittsburgh Plate Glass Export Corp.

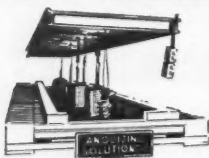
**Robert R. Freeman** has been appointed manager of arc-cast molybdenum development of Climax Molybdenum Co., New York.

**Rhea P. Lapsley** has been named vice-president in charge of research and products development of the Okonite Co., Passaic, N. J. He has had 32 years' experience in the electrical industry, joining Okonite in 1936 to open the New Orleans sales office.



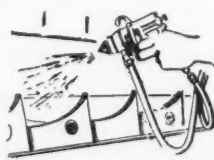
## CHROMIUM CHEMICALS IN ACTION

The useful life of modern jet aircraft has been appreciably prolonged through the application of effective corrosion inhibitors. Chromium Chemicals in various forms are used at many stages of jet plane production.



Anodizing aluminum alloy parts with chromic acid forms one of the most effective protective coatings known today. Furthermore, it is an excellent base for the customary zinc chromate primer. Steel and magnesium assemblies also are painted with zinc chromate...and before magnesium castings are primed they are dipped in a bichromate bath.

These illustrations are examples of the ability of Chromium Chemicals to inhibit and prevent corrosion. Besides supplying many industries with superior quality chromium chemicals, Mutual offers information on the numerous other ways that these chemicals help to protect valuable materials and equipment. So, if you are in doubt about the best way to solve your corrosion problem, contact Mutual.



Sodium Chromate • Chromic Acid • Sodium Bichromate  
Potassium Bichromate • Potassium Chromate



**MUTUAL CHEMICAL DIVISION**

ALLIED CHEMICAL & DYE CORPORATION

99 PARK AVENUE • NEW YORK 16, N. Y.







# CORROSION ABSTRACTS

## INDEX TO CORROSION ABSTRACTS

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## 1. GENERAL

### 1.2 Importance

#### 1.2.5

Threshold Limit Values (for Atmospheric Contaminants) for 1954. U. S. Governmental Industrial Hygienists Committee on Threshold Limits. *Arch. Ind. Hyg. Occupational Med.*, 9, No. 6, 530-534 (1954) June.

Established and tentative maximum average values of atmospheric concentrations of contaminants (gases, vapors or dusts) to which workers may be exposed for an 8-hr. day without injury to health. Metals, metallic oxides, inorganic and organic chemicals are included.—BNF.

9308

#### 1.2.5, 1.6, 2.3.9, 8.4.5

Protection Against Radiations from Radium, Cobalt-60, and Caesium-137. U. S. Nat. Bur. Stand. Handbook 54, Sept. 1, 1954, 60 pp. Available from: U. S. Supt. of Documents, Washington 25, D. C.

Handling, storage and transportation; precautions in medical and non-medical applications; protection surveys, personnel monitoring and working conditions; accidents entailing radiation hazards.—BNF.

9536

### 1.4 Bibliographies and Indexes

#### 1.4, 3.2.1, 3.5.1, 3.7.3, 2.3.7

Quantities and Reactions of Solid Surfaces: A Bibliography. (Miss) E. P. CARTER. U. S. Atomic Energy Commission Publ., ORNL-1686, 1954, 135 pp.

A bibliography of 238 comprehensive

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BL—Current Technical Literature, Bell Telephone Laboratories, Inc., Murray Hill, N. J.  
BTR—Battelle Technical Review, Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio.  
BNF—Bulletin; British Non-Ferrous Metals Research Association, 81-91 Euston St., London NW 1, England.  
CBEC—Centre Belge d'Etude de la Corrosion (CEBELCOR), 17 re des Drapeiers, Brussels, Belgium.  
CE—Chemical Engineering, McGraw Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.  
EL—Electroplating, 83/85 Udney Park Road, Teddington, Middlesex, England.  
EW—Electrical World, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.  
GPC—General Petroleum Corp. of California. 2525 East 37th St., Los Angeles 11, Calif.  
IIM—Transactions, The Indian Institute of Metals, 23-B, Notaji Subhas Road, P. O. Box 737, Calcutta, India.  
INCO—The International Nickel Co., Inc. 67 Wall Street, New York 5, New York.  
IP—Institute of Petroleum, 26 Portland Place, London W-1, England.  
JSPS—Japan Society for the Promotion of Science, Address: Mr. Hayata Shigeno, Secretary, Committee of Preventing Corrosion, c/o Government Chemical Industrial Research Institute, 1-Chrome Nakameguro, Meguro-ku, Tokyo, Japan.

MA—Metallurgical Abstracts, Institute of Metals, London, England. 4 Grosvenor Gardens, London SW 1, England.  
MI—Metallurgia Italiana, Associazione Italiana di Metallurgia. Via S. Paola, 10, Milano, Italia.  
MR—Metals Review, American Society of Metals. 7301 Euclid Ave., Cleveland 3, Ohio.  
NALCO—National Aluminate Corp. 6216 West 66th Place, Chicago 38, Illinois.  
NBS—National Bureau of Standards, Supt. of Documents, U. S. Gov't Printing Office, Washington 25, D. C.  
NSA—Nuclear Science Abstracts, United States Atomic Energy Commission, Technical Information Division, Oak Ridge, Tenn.  
PDA—Prevention Deterioration Abstracts. National Research Council, 2101 Constitution Ave., Washington 25, D. C.  
RM—Revue de Metallurgie, Paris, France. 5 Cite Pigalle, Paris (9e), France.  
RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London, Waldegrave Rd., Teddington, Middlesex.  
SE—Stahl Und Eisen, Verlag Stahlisen, M. B. H., Dusseldorf, August-Thyssen Str. 1. Postcheck Koln 4110, (22a) Dusseldorf, Germany.  
TIME—Transactions of Institute of Marine Engineers, 85 The Minories, London EC 3, England.  
UOP—Universal Oil Products, 310 South Michigan Ave., Chicago, Illinois.  
ZDA—Zinc Development Association. 34 Berkeley Square, London W.1.

abstracts of papers dealing with the study and properties of surfaces, classified as follows: 1.) measurements of surface quantities: area, roughness, tension; 2.) physico-chemical reactions: adsorption, cleaning, polishing, oxidation, states; and 3.) physico-mechanical reactions: friction, lubrication, mechanical polishing, mechanical wear.—MA. 9580

## 1.6 Books

### 1.6, 3.5.3, 3.5.8

**The Friction and Lubrication of Solids.** F. P. BOWDEN AND D. TABOR. Book (second edition), 1954, 372 pp. Oxford University Press, Amen House, London, E.C.4.

In this edition, the 337 pages of the first edition are reprinted with the addition of a section (35 pp.) covering developments in the interim.—BNF. 9498

## 2. TESTING

### 2.2 On Location Tests

#### 2.2.3, 2.3.5, 3.6.6

**Corrosion.** M. G. FONTANA. *Ind. & Eng. Chem.*, 47, No. 4, 89A-91A (1955) April. Describes procedures for galvanic or 2-metal corrosion tests. Several galvanic corrosion assemblies are illustrated. Ratio of anode area to cathode area or area effect is considered and illustrated by tests on riveted joints in sea water made by INCO at Harbor Island. Specimens of copper plates with steel rivets and steel plates with copper rivets were exposed in ocean for nine months. Steel rivets were completely corroded in first case but joint with copper rivets was still good. Author concludes that for most plant work, potential studies are not justified and there is no substitute for a galvanic corrosion test under actual operating conditions.—INCO. 9998

## 3. CHARACTERISTIC CORROSION PHENOMENA

### 3.5 Physical and Mechanical Effects

#### 3.5.9, 4.3.3, 3.8.4

**The Liquidus of Metal-Oxide/Vanadium Pentoxide Systems and the Mechanism of Accelerated Attack on Metals by Vanadium Pentoxide.** G. LUCAS, M. WEDDLE AND A. PREECE. *J. Iron & Steel Inst.*, 179, Pt. 4, 342-347 (1955) April; *Iron and Steel*, 28, 264-267 (1955) May.

Suggests an approach to the problem of heat-resistant alloy attack by the development of alloys which would depend on some element, other than chromium, for their oxidation resistance, or by prevention of  $V_2O_5$  reacting with the protective oxide film. Liquidus of a number of vanadium pentoxide/metal-oxide systems, including those of aluminum, cobalt, chromium, magnesium, nickel, copper, iron and chromium-nickel, was determined using the Seger cone method. Study was also made of the attack of vanadium pentoxide on chromium at high temperatures. Results have shown that alloys which resist oxidation by virtue of a protective film of chromium oxide lose this property in the presence of vanadium pentoxide. Investigations were made as a result of the corrosive attacks of gas-turbine blades by vanadium pentoxide. Graphs. 10073

#### 3.5.9, 6.3.6

**Effects of Temperature on the Deformation of Beta Brass.** C. S. BARRETT. *J. Metals* (Trans. A.I.M.E.), 6, No. 9, Section 2, 1003-1008 (1954) Sept.

Measurements of impact hardness have been made at 20° and at 275-525°C. Abrupt softening (accompanied by abrupt widening of deformation bands in the deformed samples) is observed above 425°C. Theoretical aspects of these effects and the lack of twinning.—BNF. 9338

#### 3.5.9, 3.5.8

**Creep Correlations of Metals at Elevated Temperatures.** O. D. SHERBY, R. L. ORR AND J. E. DORN. *J. Metals* (Trans. A.I.M.E.), Section 1, 6, No. 1, 71-80 (1954) Jan.

Equations which correlate creep data of pure metals at temperatures above which rapid recovery occurs are applied to aluminum, iron, nickel, copper, zinc, platinum, gold and lead, and to simple alloys.—BNF. 9462

#### 3.5.9, 7.1, 8.9.1

**Application of High Temperature Materials to Aircraft Power Plants.** A. LEVY. Marquardt Aircraft Co. *Automotive Inds.*, 112, No. 6, 235, 368, 370, 374, 376, 378, 380, 384, 386, 388, 393, 396, 398, 403-404, 406-407 (1955) March 15.

Materials available for service at temperatures of 1200 degrees F and up are discussed. Alloys retaining sufficient strength in this range have iron nickel and cobalt as major constituents. Iron base alloys used up to 1500 degrees F are listed as Types 321, 347 and 310 stainless steels, 19-9DL, 19-9DX, 16-25-6, A-286, 17-4 PH, 17-7 PH and Discalloy 24. Nickel base alloys used from 1500-1800 degrees F are listed as Inconel, Inconel X, Incoloy, Nimonic 75, 80, 90 and Hastelloy B, C, X. Cobalt base alloys used from 1600-2200 degrees F are listed as N-155, S-816, Refractalloy 70, L-605 (H.S. 25), and H.S. 21, 23, 30 and 31. Considerations in selecting a metal for elevated temperature application including mechanical and physical properties, fabrication characteristics, scaling and corrosion resistance and cost are discussed. Applications of the various alloys in turbojet afterburners, ramjet engines and in rockets are covered. Tables.—INCO. 10081

### 3.6 Electrochemical Effects

#### 3.6.6, 6.2.3, 6.3.6

**Corrosion of Metals in Alkaline Solutions. Second Rept. On the Contact Corrosion of Dissimilar Metals. Pt. II. Mild Steel-Phosphorus Bronze.** H. ENDO AND N. OOTANI. *J. Japan Inst. Metals*, 18, No. 6, 333-337 (1954) June.

Experiments in sodium sulfate and sodium carbonate solutions at 30° led to the following relation ( $V$ , potential difference of the two metals;  $\rho$ , the specific resistance of solutions;  $\gamma$ , the limiting current density at anodic surface; and  $\Delta W$  the galvanic corrosion loss of mild

$$\text{steel): } \Delta W = 3.1 \times 10^4 \frac{V}{\rho}$$

$$\log \left( 1 + \frac{11.6 \rho}{\gamma} \right). \text{ Furthermore the following items were cleared up.}$$

1.) In stagnant state, the maximum point of  $\Delta W$  is reached at pH = 10.5 in sodium carbonate solution. At pH < 10.5,  $\Delta W$  is controlled mainly by  $V$ , and  $\gamma$  cathodic depolarization, but at pH > 10.5, it is controlled mainly by de-

crease of  $V$  and anodic polarization. 2.) In sodium carbonate solution, the decrease of  $\Delta W$  of mild steel with increase of r.p.m. is based on the decrease of  $V$  and anodic polarization. The fact that the pH value at which the maximum point of  $\Delta W$  is obtained shifts to smaller values by revolution seems to be caused by anodic polarization due to the increase of diffusion amount of  $\text{OH}^-$ . 3.) On the contrary, in sodium sulfate solution,  $\Delta W$  increases by revolution and this because anodic polarization is affected differently by the kind of anion ( $\text{CO}_3^{--}$  or  $\text{SO}_4^{--}$ ) in the solution.—JSPS. 9555

## 3.8 Miscellaneous Principles

### 3.8.2, 3.6.8

**Corrosion and Corrosion Research.** THOMAS R. CAMP. *Proc. Am. Soc. Civil Engrs*, 81, Separate No. 685, 685-1-685-26 (1955) May.

A comprehensive study on corrosion is presented. Elements of the corrosion cell are described and it is demonstrated that a great variety of half-cell reactions are possible whose single electrode potentials may be computed from thermodynamic constants and the composition of the aqueous solution with which the metal is in contact. It is also demonstrated that only those half-cell reactions which produce the greatest electromotive force can take place. The method identification of the half-cell reactions for a particular case is illustrated. It is shown that the theory may be used to great advantage in selecting water treatment processes for corrosion control. The theory underlying the correct procedure for polarization tests is developed and it is shown that all unknowns may be evaluated if the single electrode potentials are computed first.—ALL. 9979

#### 3.8.2, 4.3.2

**Electrochemical Studies of the Hydrogen Sulfide Corrosion Mechanism.** SCOTT P. EWING. *Corrosion*, 11, No. 11, 497-501 (1955) November.

A statement of the anodic and cathodic reactions in the hydrogen sulfide corrosion process is given along with experimental evidence to indicate that these reactions are the important ones. The corrosion process is explained further in terms of the electrochemical properties of the corroding solution and the corrosion products. Results of laboratory experiments indicate that the description of the mechanism is correct. The possible usefulness of an understanding of the corrosion process is demonstrated by a few practical application. 10299

#### 3.8.2, 5.8.3, 3.6.5

**Zero Charge Potential and Action Mechanism of Inhibitors of Acidic Corrosion of Iron.** (In Russian.) E. O. ATAZIAN. *Doklady Akad. Nauk SSSR*, 100, No. 3, 473-476 (1955) January 21.

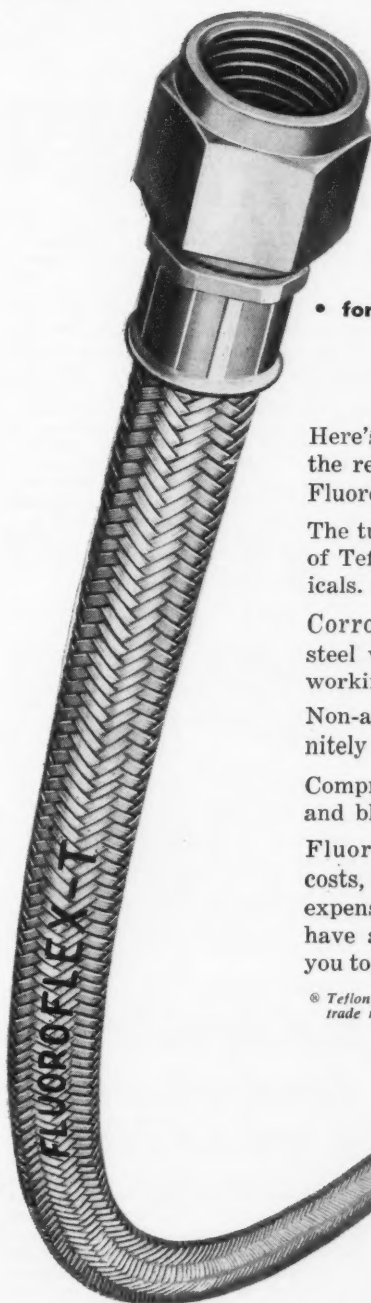
Cathode polarization curves of iron; relation of double layer capacity to the potential on iron in sulfuric acid. Graphs, circuit diagram, Six references.—BTR. 9930

#### 3.8.2, 3.6.8, 6.3.15

**Electrochemical Behavior of a Titanium-Fused Salt-Platinum Cell.** M. E. STRAUMANTIS AND A. W. SCHLECHTER. Paper before Electrochem. Soc., Chicago, May 2-6, 1954. *J. Electrochem. Soc.*, 102, No. 3, 131-136 (1955) March.

Cell, titanium/sodium chloride or potassium chloride fused/platinum above 800 degrees C and in air, displays a substantial open-circuit potential difference

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of 1.40-1.53 v. In vacuum or under an inert gas the difference is 0.5 v, and current that can be drawn from such a cell is low. Air, oxygen, and water vapor act as cathodic depolarizers, maintaining a positive potential of the cathode and an appreciable current if the cell is short circuited. Alkali oxides are produced on cathode if a salt containing titanium ions is electrolyzed in presence of air. Under an inert gas the discharge of alkali ions hampers the deposition of titanium, which is then produced in the form of a powder. Tables, graphs and 7 references.—INCO. 9883

3.8.4, 6.4.2, 6.2.3

**Corrosion and Heat of Activation.** (In German.) MAX WERNER. *Werkstoffe u. Korrosion*, 6, No. 3, 113-117 (1955) March. Corrosion of aluminum and steel caused by different corrosive agents. Graphs, diagram. 4 references.—BTR. 9880

#### 4. CORROSIVE ENVIRONMENTS

##### 4.3 Chemicals, Inorganic

4.3.2, 3.5.11, 2.3.4

**Rate of Flow as Factor of Special Importance in Corrosion by Sulfuric Acid.** H. W. HOEVEN. *Werkstoffe u. Korrosion*, 6, 57-62; disc., 62 (1955) Feb.

Short review of available data on corrosion by sulfuric acid from which it is concluded that laboratory data do not permit critical selection of materials for practical applications. Description is given of new laboratory test method developed to permit measurement of corrosion under different conditions of flow. Investigation was made of effect of accumulation of corrosion products in the attacking solution. Data are presented of measurements on carbon steel and nickel-aluminum bronze.—INCO. 10035

4.3.2

**The Corrosivity of Fuming Nitric Acid.** JOHN D. CLARK and MICHAEL A. WALSH. *Trans. N. Y. Acad. Sci.*, 17, 279-288 (1955) Feb.

Mechanism of corrosion of SS-347 in the red and white acids (97 to 98% acid) is evolved. Graphs. Two references.—BTR. 9938

4.3.2, 6.6.8

**Plastics for Strong Nitric Acid Service.** E. J. ZEILBERGER. *Materials & Methods*, 41, No. 4, 102-104 (1955) April.

Successful use of polyethylenes, fluorocarbons and polyvinylchlorides as tank liners, coatings, O-rings and gaskets in nitric acid service is discussed. Illustrations.—INCO. 9845

4.3.2

**Thermal Properties of Commercial White Fuming Nitric Acid.** T. R. BUMP, P. F. PAGREY, J. P. KERN, D. W. FYFE, C. R. ST. CLAIR and W. L. SIBBITT. *Jet Propulsion*, 25, No. 4, 170-172, 180 (1955) April.

Application of commercial white fuming nitric acid with various engine fuels as rocket propellants prompted investigation of physical properties of the acid. Data necessary for heat transfer and pressure drop calculations (thermal conductivity, viscosity, specific heat, density and total pressure) were measured and are compiled for -30 to 300 degrees F. Vapor-pressure bombs of glass, H.S. 25 (L605), and Type 347 were used to determine total pressure at 200-300 degrees



F. Metallic compounds picked up by the acid from the stainless steel storage tank introduced errors in determining concentration of test acid. Graphs, 16 references.—INCO. 9939

#### 4.3.5, 7.5.2

**An Efficient Vacuum-Jacketed Liquid Nitrogen or Liquid Oxygen Storage Vessel.** N. C. HALLETT, H. W. ALTMAN, M. L. YEAGER AND C. L. NEWTON. Paper before Cryogenic Eng. Conf., Boulder, Colo., Sept. 8-10, 1954. Nat'l. Bur. Standards Rept. No. 3517, February, 1955, 5-7.

Herrick L. Johnston 600 liquid oxygen or liquid nitrogen vessel is manufactured for the storage, transfer and transport of liquefied gases. Liquid container of 304 stainless steel is suspended axially within an outer shell of 1020 low carbon steel. Diagram and illustrations.—INCO. 10044

#### 4.3.5, 7.5.2

**The Herrick L. Johnston Air Tactical Dewar.** C. B. HOOD, JR., H. W. ALTMAN, M. L. YEAGER, N. C. HALLETT AND L. D. WAGNER. Paper before Cryogenic Eng. Conf., Boulder, Colorado, September 8-10, 1954. National Bureau of Standards Report No. 3517, February, 1955, 24-26.

Johnston design of Air Tactical Dewar consists of inner stainless steel shell, with a capacity of 750 liters of liquid hydrogen; liquid hydrogen reservoir, with capacity of 500 liters, built into the dewar to maintain a copper radiation shield at liquid nitrogen temperature; outer shell of stainless steel; and built-in vacuum pump and instrumentation. Diagram.—INCO. 10276

#### 4.3.5, 7.5.2

**Experimental Dewars Developed by the National Bureau of Standards.** B. W. BIRMINGHAM, E. H. BROWN, C. R. CLASS AND A. F. SCHMIDT. Paper before Cryogenic Eng. Conf., Boulder, Colorado, September 8-10, 1954. National Bureau of Standards Report No. 3517, February, 1955, 27-32.

Report on development of 400-liter and 750-liter dewars for transport of liquid hydrogen. Stainless steel, copper, copper alloys. Monel and aluminum were considered for construction materials because of good impact properties at low temperatures. It was decided to use aluminum for all shells on the 400-liter experimental dewar with stainless steel for internal piping and stainless steel, copper and brass for exterior valves and piping. Suspension system used in this application was formed from thin stainless steel. Table and diagrams.—INCO. 10242

#### 4.3.5, 5.4.8

**Guards Against Corrosive Iodine Fumes.** EDGAR B. WITMER AND ROY HELSING. *Chem. Processing*, 18, 76-77 (1955) May.

Controlled with a chlorinated rubber-base enamel. Photographs.—BTR. 9892

#### 4.3.5, 3.5.9

**Effect of Temperature on the Corrosion of Metals by Chlorine.** (In Russian.) Kh. L. Tseitlin. *J. Applied Chem., USSR* (Zhurnal Prikladnoi Khimii), 28, No. 5, 490-496 (1955) May.

Two groups of metals in terms of their resistance to dry chlorine at a high temperature. Release of heat during reactions. Special resistance of lead despite its low melting point. Effect of chlorine contrasted to that of other gases. Table, graph, micrographs. 9 references.—BTR. 9874

#### 4.3.6

**Resistance to Corrosion of Various Metals in Soda-Potash and Soda-Sulfate Solutions.** (In Russian.) V. G. INZHECHIK AND A. V. IANUSH. *Chemical Industry* (Khimicheskaya Promyshlennost'), No. 1, 39-42 (1955) Jan.-Feb.

Laboratory and plant tests of corrosion rates; effect of temperature and covering atmospheres; comparative resistance of different steels and irons. Graphs, tables.—BTR. 10304

#### 4.3.7, 8.6.1, 8.6.2

**Mechanical Dishwashing Detergents.** K. ALBRECHT. Calgon, Inc. Paper before Chem. Specialties Mfrs. Assn., New York, December 9, 1954, 41st Ann. Mtg. *Soap & Chem. Specialties*, 31, Nos. 1, 2, 33-35; 44-45, 71 (1955) Jan., Feb.

Background of development of effective detergents, culminating in trials of detergent consisting essentially of chlorinated trisodium phosphate and sodium tripolyphosphate, with available chlorine content of approximately 2%. In commercial dishwashing, problems include spotting of silver if not properly rinsed, desincification of copper-zinc alloy machine parts in soft water and turning of exposed base metal of worn silverplate to a brassy gold color. Black spotting on silverware due to contact with solid particles of dissolved chlorinated phosphate is among problems in home dishwashing. Corrosion of aluminum kitchen utensils and aluminum dishwasher parts is a serious problem.—INCO. 10285

### 4.4 Chemicals, Organic

#### 4.4.6

**Washing System Cleans up Residual Fuel for Low-Cost Gas-Turbine Operation.** D. M. LANDIS. De Laval Separator Co. *Power*, 99, No. 7, 78-80 (1955) July.

To prevent or minimize corrosion by residual fuels fired in high-temperature furnaces, caused by vanadium and sodium in the ash, wash system was developed which removes sodium from oil. This eliminates slag formation augmented by addition of inhibitors. Once rid of sodium, additive to prevent vanadium corrosion is incorporated in form of a water solution of magnesium sulfate, thoroughly mixed with fuel to form an emulsion. Flow sheet.—INCO. 10452

#### 4.4.6

**Modified Residual Fuel for Gas Turbines.** B. O. BUCKLAND AND D. G. SANDERS. Paper before Am. Soc. Mech. Engrs., Ann. Mtg., New York, November 28-December 3, 1954. *Trans. ASME*, 77, No. 8, 1199-1208; disc., 1208-1209 (1955) Nov.

Sodium in gas-turbine fuel causes rapid deposit formation as well as corrosion. Paper describes method in use at Rutland plant of Central Vermont Public Service Corp. for removing most of the sodium and part of calcium from fuel. Turbine tests of 50-1500 hours' duration using desalted fuels show that deposit is almost eliminated by keeping sodium and calcium below 10 parts per million. Specification is proposed, defining fuel which can be obtained at point of use by desalting method described and by adding water solution of magnesium sulfate to fuel just before it is burned. Below 1650F, magnesium is a better inhibitor than calcium for vanadium-containing fuels. Lead in fuel spoils inhibition of vanadium by magnesium. Data are presented for corrosion tests on Type 310 specimens in a small-burner rig. Tables, graphs.—INCO. 10741

### 4.5 Soil

#### 4.5.1, 6.2.2

**On the Mechanism of the Corrosion of Iron in Soils.** (In German.) T. MARKOVIC, Z. DUGI AND B. SRIBAR. *Werkstoffe & Korrosion*, 6, No. 7, 334-337 (1955) July.

The rate of corrosion of iron depends on the pH-value of the soil if the corrosion of the iron takes place under an excess of oxygen. Laboratory experiments with soft steel specimens show that corrosion of iron in unsaturated soils is a reaction of the first order, in water-saturated soils it follows the law of diffusion. Graphs, tables.—BTR. 10546

#### 4.5.2, 5.4.5, 5.2.1, 7.2

**Protection of Underground Pipelines—Mechanical and Cathodic.** J. E. CARRIERE. Report to the Intern. Water Supply Congr. *Fluid Handling*, No. 68, 253-256 (1955) Sept.

Reports results of studies in Europe and Australia, with emphasis on work by the Netherlands Corrosion Committee, on chemical investigation of soils, behavior of cast iron and steel pipes in various types of soils, asphaltic bitumen and coal-tar coatings, effectiveness of various types of fibre glass wrappings, penetration by some plant roots through bitumen coatings, asbestos-cement pipes and use of cathodic protection.—INCO. 10732

### 4.6 Water and Steam

#### 4.6.1, 5.7.9

**A Note on the Efficacy of an Apparatus for the Magnetic Treatment of Water.** (In French.) J. LAUREYS, J. VAN MUYLDER AND N. POURBAIX. *Brochure*, May 30, 1955, 15 pp. Centre Belge d'Etude de la Corrosion, 21 Rue des Drapiers, Brussels, Belgium.

The report covers reproducibility of results, and influence of magnetic treatment on Brussels water, including pH, iron content and morphology of carbonate and calcium crystals. Also included are notes on the effect of magnetic treatment on the functioning of a still. 10442

#### 4.6.1

**Non-Ferrous Metals in the Water Industry.** E. C. MANTLE. *British Waterworks Assoc. J.*, 37, No. 281, 98-101 (1955) Feb.

A concise discussion of investigations undertaken by the Brit. Non-Ferrous Metals Res. Assoc. on problems arising in the use of non-ferrous metals in water supplies: copper water pipes; galvanized tanks and cisterns; aluminum; soil corrosion. Reprints are available from BNFMR as R. & C. 260.—BNF. 10886

#### 4.6.1, 1.2.2, 5.7.1, 5.8.2

**An Economic Analysis of Water Treatment.** M. C. FORBES. *Petroleum Engr.*, 27, No. 10, C34, C36-C37, C40-C42 (1955) September.

Defines the problems to be faced in an economic analysis of water treatment, evaluates the results of using a treatment of less than maximum effectiveness and aids in estimating costs of chemicals and equipment. Specific problems of microbiological control, scale control and corrosion control are considered. Mechanical treatment by aeration, deaeration, sedimentation and filtration and chemical treatment by hot lime-soda softening and ion exchange are analyzed. Graphs present cost data for lime-soda, sodium zeolite and hydrogen zeolite softening

systems. Addition of chromium salts as corrosion inhibitors is discussed.—INCO. 10824

## 4.6.1.1.6

**Report of Committee D-19 on Industrial Water.** American Society for Testing Materials, Preprint 52, 1955, 67 pp.

Includes tentative methods of test for the analysis of water and specifications for: Acidity and Basicity (Alkalinity) in Industrial Water and Industrial Waste Water. ASTM Designation: D 1067-55T (pp. 27-32); Iron in Industrial Water and Industrial Waste Water. ASTM: D 1068-55T (pp. 33-39); Fluoride Ion in Industrial Water and Industrial Waste Water. ASTM Designation: D 1179-55T (pp. 40-46); Reagent Water. ASTM Designation: D 1193-55T (pp. 47-48); Chloride Ion in Industrial Water and Industrial Waste Water. ASTM Designation: D 512-55T (pp. 49-52); Phosphate in Industrial Water. ASTM Designation: D 515-55T (pp. 54-62); Sulfate Ion in Industrial Water and Industrial Waste Water. ASTM Designation: D 516-55T (pp. 63-67).—BNF. 10687

## 4.6.1.5.7.1

**Water: How It's Treated.** E. NORDELL. Permit Co. Chem. Eng., 62, No. 10, 175-184 (1955) Oct.

Reviews the main types of water-conditioning processes: sodium cation exchange; hydrogen cation exchange; ion exchange demineralization using both cation and anion exchangers; cold lime soda; hot lime soda; coagulation, settling and filtration; aeration; deaeration, and iron and manganese removal. Table gives approximate chemical requirements.—INCO. 10834

## 4.6.2

**Stop Losing Your Heating-System Dollars to Corrosion.** Power, 99, No. 1, 118-119 (1955) January.

Proper water treatment and a tight system slow down internal corrosion losses, care in pipe laying checks external attack. Oxygen and carbon dioxide are biggest trouble makers. Table.—BTR. 10616

## 4.6.2

**Practical Condensate Corrosion Control.** O. L. HUDRIK. Paper before TAPPI, Pacific Sec., Tacoma, September 29, 1955. Tappi, 38, No. 11, 152A-154A (1955) November.

Emphasizes importance of best possible boiler feedwater pretreating plant and discusses deaerating, volatile amines and film-forming chemicals as corrosion control measures. Amines and film formers have own distinct applications and are not interchangeable. Heat transfer retardation by corrosion deposits is considered.—INCO. 10803

## 4.6.2, 3.8.4, 7.2

**Formation of Protective Layer and Steam Decomposition (Cracking) in Steel Pipes at High Temperatures.** (In German.) E. ULRICH. Brennstoff-Wärme-Kraft, 7, No. 6, 241-248 (1955) June.

Decomposition of steam into oxygen and hydrogen at high temperatures and its influence on inside surface of steel pipes. The theory of the phenomenon. Diagram, graphs, tables, 12 references.—BTR. 10338

## 4.6.2, 5.8.2, 5.7.7

**Connecticut Light and Power Company Reports Experience with Hydrazine in Reheat Cycle.** R. T. HESS AND A.

W. WOFFORD. Power Eng., 59, No. 9, 80-84 (1955) September.

Describes unique application of hydrazine plus sodium sulfite and morpholine simultaneously in a single feedwater-steam-condensate system, and operating data observed during such treatment. Flowsheets, tables, graphs.—INCO. 10778

## 4.6.2, 5.8.2

**Hydrazine Finds New Field; Industrial Plants.** R. V. MONTVILLE, G. R. JENKINS AND E. R. WOODWARD. Power, 99, No. 3, 99-102 (1955) March.

Hydrazine is being used successfully as an oxygen scavenger in feedwater at the Doe Run petrochemical plant in Brandenburg, Ky. Simple, adequate methods for control of residual hydrazine

in boiler water are covered. Advantages of using hydrazine as an oxygen scavenger are numerous and these are listed. Flow diagram.—INCO. 9824

## 4.6.4, 5.8.2

**How to Calculate Age of Water Treatment.** M. BROOKE. Petroleum Refiner, 34, No. 8, 122 (1955) August.

Addition of chemicals into a closed circulating cooling water system results in loss of some of the chemicals and degradation of others into inactive forms. Polyphosphate scale inhibitor tends to revert to an orthophosphate under cooling tower conditions. Formula for calculating amount of treating chemicals removed daily in blowdown is given.—INCO. 10470

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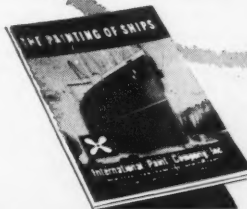
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## 5. PREVENTIVE MEASURES

### 5.3 Metallic Coatings

#### 5.3.2, 2.3.7

**Hardness and Wear Resistance of Electrodeposits.** (In German.) R. WEINER AND G. KLEIN. *Metalloberfläche*, Sec. B, 7, No. 1, 1-7 (1955) January.

Micro-indentation hardness, scratch hardness and abrasion loss tests were carried out on a large number of deposits (brass, bright and hard chromium, bright and dull nickel, various copper, bright and dull silver, various zinc, bright and dull cadmium). No clear-cut correlation is found between the three quantities. In particular, indentation hardness and abrasion resistance cannot be related, rather does the latter correspond to scratch hardness. Considerable reduction in scratch hardness compared with indentation hardness generally suggests low abrasion resistance. Bright deposits from special baths are not harder throughout than those from normal baths; even where indentation hardness of a bright deposit is higher than in the normal deposit, the abrasion resistance can be lower.—BNF. 9875

#### 5.3.2

**Alternative Finishes.** A. W. WALLBANK. *Metal Ind.*, 86, No. 4, 70 (1955) January 28.

It is pointed out that while tin-nickel alloy coating is satisfactory in protective value, after exposure to atmosphere it appears less lustrous than chromium over nickel because the luster of chromium is better through a dust film than that of tin-nickel alloy coating. See also letter by W. R. Lewis [*ibid.*, 86, No. 2, 32 (1955) January 14].—BNF. 9846

#### 5.3.2, 3.5.8

**Flecks Appearing on the Surface of Electroplated Metal Subjected to Repeated Stress.** M. SUZUKI. *Bull. Inst. Metals*, 2, No. 19, 227 (1955) March.

Okubo has found that copper electrodeposits on carbon-steel exhibit "flecking" when test-pieces are subjected to torsional fatigue above a critical stress. Present author finds similar behavior in copper electrodeposits on brass stressed in torsion and rotating bending; maximum value of cyclic stress did not exceed the endurance limit of the brass. Disposition of flecks indicates position of principal shear stress.—BNF. 9854

#### 5.3.2, 2.3.7

**Porosity of Electrodeposited Metals.** N. THON, D. G. KELEMEN, L. YANG, S. YANG AND D. DEAN. *Am. Electroplaters' Soc. Research Rept.*, Ser. No. 28, 5-28 (Rec'd 1955).

AES Project No. 6 reports on hydrogen content of electrodeposited nickel; analysis of corrosion products as a method of measuring the change of porosity in corrosion (nickel coatings tested); measurement of surface roughness and its change in exposure; and an improved permeability apparatus by means of which measurements were made over larger nickel foil areas. Tables and graphs.—INCO. 9860

#### 5.3.2, 2.3.7

**Testing the Uniformity of Zinc Coatings on Steel Wire by the Copper Sulfate Method.** G. SCHIKORR. *Draht*, English Edition No. 15, 43-45 (1955) Feb. Technique for determining thickness

and uniformity of zinc coatings by a combination of acid immersion and cupric sulfate methods. Total zinc deposit was determined by loss in weight of a length of wire after dissolving zinc in fuming hydrochloric acid containing 32 g/l antimony trichloride. Immersion tests in cupric sulphate solution were carried out either exactly according to German standard practice (1 part by wt.  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  in 5 parts by wt. of distilled water) or with a more highly concentrated solution (1 part  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  in three parts distilled water). Tests show that satisfactory quality evaluation of zinc coatings on steel wire may be arrived at by cupric sulfate immersion method if, instead of number of immersions, total loss in weight due to quantity of zinc dissolved during immersions is used as a measure. Modification of cupric sulfate immersion method, using more concentrated solution, is suggested as means of making direct determination of total zinc coating unnecessary. Tables, graphs, 6 references.—INCO. 9831

#### 5.3.2

**The Use of Clad Metals.** H. SCHWARTZ. *Product Eng.*, 26, No. 6, 162-166 (1955) June.

Fifteen types of composite materials, including stainless steel-on-low carbon steel, stainless-on-copper, copper-on-low carbon steel, phosphor bronze-on-copper, nickel-on-low carbon steel, Monel-on-low carbon steel, stainless-on-Invar, silver-on-copper, silver-on-phosphor bronze, silver-on-beryllium copper, copper-on-beryllium copper, silver-on-nickel, gold-on-copper, gold-on-nickel, and gold-on-brass; design functions; applications, and limitations are described and tabulated.—INCO. 9816

#### 5.3.4

**Hot Dip Galvanizing Is a Science.** W. G. IMHOFF. *Wire & Wire Products*; 30; Nos. 2, 3, 4, 5, 6; 167-170, 233-235; 295-297; 437-438, 487-490; 553-556, 605; 681-683, 726-727 (1955) Feb., March, April, May, June.

Principles of hot dip galvanizing are covered. First principle states that the higher the galvanizing bath temperature, the heavier the deposit of zinc and, conversely, the lower the bath temperature, the lighter the coating of zinc. Second principle states that the heavier the gage of the base metal, the heavier the zinc deposited as a galvanized coating; and principle number three is that the longer the submersion time in the molten bath the heavier will be the zinc deposited as a galvanized coating. Results are tabulated. Graphs.—INCO. 10022

#### 5.3.4

**Electroplated Versus Electroless Nickel.** N. HALL. *Metal Finishing*, 53, No. 2, 51 (1955) February.

An editorial article which says that claims regarding absence of porosity and labor saving in electroless plating of nickel are overrated: the electroless nickel solution must be well filtered and under conditions of good filtration, nickel can be electrodeposited practically porosity-free as low as 0.0001-0.0002-inch thick. Electroless nickel is said to be a very useful tool where electrodeposition is impracticable.—BNF. 10021

#### 5.3.4, 6.4.2

**Electroplating on Aluminum.** R. F. HAFFER. *Reynolds Metals Co. Metal Progress*, 67, No. 5, 93-97 (1955) May.

Careful surface preparation is needed to obtain sound and adherent electrode-

posits on aluminum. Basic ideas evolved to obtain adherence include anodizing and immersion plating to form suitable initial films of metals. Operating conditions for anodizing with phosphoric acid are tabulated. Sodium zincate or zinc immersion process is being used commercially at present to preplate aluminum and its alloys for subsequent electroplating. Basic procedures for this process, including cleaning, surface conditioning, zincating and electroplating are discussed. Copper, nickel, silver, cadmium and brass can be plated directly on zinc deposit from suitable plating solutions. Applications include jewelry, hardware, electrical equipment and engine cylinders and pistons.—INCO. 9993

#### 5.3.4

**Automatic Control Permits Plating Cell Selection.** T. J. DOYLE. *Gen. Motors Corp. Machinery*, 61, No. 7, 180-187 (1955) March.

Pontiac bumpers are plated uniformly at high production rates on a 480-ft. long, straight-line, automatic machine built by Udylyte Corp. Tanks of various lengths are divided into cells that are automatically selected in sequence by means of unique electrically controlled, hydraulically operated devices, according to length of submerged time. Operations performed in various numbered tanks are identified in a table. A nickel-strike is employed to insure good adhesion between copper- and nickel-plating and to prevent tarnishing between copper- and nickel-plating operations. Plating installations and automation devices are described in detail and typical operational sequences are outlined. Illustrations, diagrams.—INCO. 10030

#### 5.3.4

**Influence of Surface Condition on Galvanizing Properties of Steel Sheets.** H. BABLIK. *Metal Finishing J.*, 1, No. 1, 5-10 (1955) January.

As understood in Central Europe the "dry" process of galvanizing implies that the bath (not flux-covered) contains sufficient aluminum to prevent formation of iron-zinc alloy layers in the coating. Reasons for the inhibition of the iron-zinc reaction; effect of surface condition and composition of steel sheet (as affected by working and annealing operations) on the appearance of the coating.—BNF. 10206

#### 5.3.4

**Advances in Stannate Tin Plating: the Potassium Stannate Bath.** J. W. CUTHBERTSON. *Ind. Finishing*, 8, No. 79, 21-24, 26-27 (1955) Jan.

Comparison of sodium and potassium stannate plating solutions; limitation of sodium stannate and some data on composition, efficiency and operation of potassium stannate bath; application to continuous electro-tinning of wire and to preparation of plated sheet.—BNF. 9970

#### 5.3.4, 6.4.2

**Softening of Aluminum Alloys by Metal Spraying.** W. A. BAKER AND E. A. G. LIDDARD. *Metal Ind.*, 86, No. 11, 216 (1955) March 18.

Investigations are in progress at the Brit. Non-Ferrous Metals Res. Assoc. and Fulmer Research Institute on the use of sprayed aluminum and aluminum-zinc coatings to protect high-strength aluminum alloys from corrosion and stress-corrosion. It has been found that these high-strength alloys in thin pieces (e.g., strips) can be overheated and soft-



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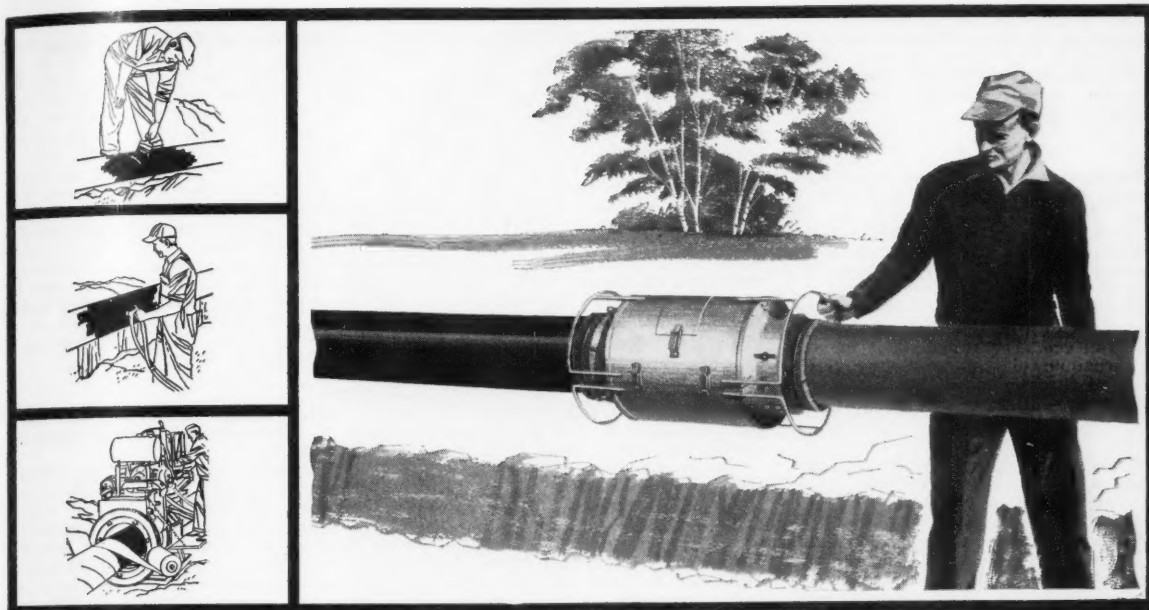
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tened by carelessness in the spraying process, e.g., holding the nozzle close to the work. In view of the potential value of the sprayed coating, the importance of proper technique in spraying is emphasized.—BNF. 9919

### 5.3.4

**Standardized Testing of Chromium Plating Baths in the Hull Cell with a Bent Cathode.** (In French.) R. H. ROUSSELOT. *Chrome Dur*, 1955, 21-32. Published by Centre d'Information du Chrome Dur, Grand Palais, Porte C, Paris 8.

Method of estimating covering power by the use of a bent cathode in a standard Hull cell. The technique is applied to chromium plating solutions over a range of chromic and sulfuric acid concentrations.—BNF. 9902

### 5.3.4

**Notes on Experiments in Electrodeposition with Perfluorinated Acids.** J. K. TAYLOR AND A. BRENNER. *Plating*, 42, No. 4, 413-414 (1955) April.

Attempts to electrodeposit chromium, nickel and cobalt from trifluoroacetate and perfluorobutyrate baths. No marked success was achieved; the nickel deposits were harder than deposits from the Watts bath, but were not outstanding.—BNF. 9868

### 5.3.4, 6.3.15

**Electrolytic Cell for Titanium.** B. W. WHITEHURST. *Steel*, 136, No. 16, 107 (1955) April 18.

Process conceived by Carlsyle uses an electrolytic cell which plates titanium on a wire or rod of titanium from low temperature molten salt in which rutile or ilmenite is dissolved. Metal is withdrawn continuously in rod form. Cell uses an inorganic electrolyte operating below 400 degrees F. It is kept at ordinary pressure and does not require an inert atmosphere. Cathode efficiency is about 98%. Purity of metal is about 99.7%, and physical tests on deposited titanium show tensile strength of 50,000 psi nominal; yield, 30,000 psi nominal; elongation in 2 inches, 35%; and Brinell hardness, 90. Process may also be used for plating titanium on other metals for corrosion protection.—INCO. 9871

### 5.3.4

**Notes on Electroplating Metallized Surfaces.** S. WEIN. *Products Finishing*, 19, No. 5, 24-26, 28, 32, 34, 36 (1955) February.

Plating metallized surfaces with nickel, copper, gold and iron is discussed.—INCO. 9882

### 5.3.4, 5.9.3

**Effect of Basis Metal Condition on Plating. Part I. Taper Sectioning of Basis Metal Surfaces and Electrodeposits.** A. E. R. WESTMAN AND F. A. MOHRNHEIM. *Am. Electroplaters' Soc. Research Dept.*, Ser. No. 30, 4-8 (Rec'd 1955).

Improved method of taper sectioning is described that enables it to be reduced to a routine operation. Origin of the "palisade layer" is established as the result of controlled etching experiments and an investigation of the flatness of taper sections by interferometry. Taper sections of nickel-plated steel panels are shown. A study, by taper sectioning, of the surface effects produced in low and high-carbon steels subjected to blasting by various abrasives is also described. Photomicrographs, 7 references.—INCO. 9849

### 5.3.4

**Bumper Guards.** M. WEINBERG AND A. LAKE. *Plating*, 42, No. 2, 144-146, 159, 179 (1955) February.

Processing of bumper guards utilizing a nickel strike instead of the conventional copper strike in the plating procedure is described. Most important feature of this strike is that it is capable of giving better bond between bright nickel and steel. It is preferred after nickel striking to go into the bright nickel with work cathodic to obtain the best adhesion. After nickel plating, the parts are rinsed twice and chromium plated. Guards are then rinsed in cold water with a spray rinse as they emerge. A hot rinse follows.—INCO. 9851

### 5.3.4

**Metallic Coatings on Non-Metallic Materials. Part I. Copper Films.** S. WEIR. *Ind. Finishing*, 8, No. 8, 94, 96, 98-99 (1955) February.

Copper films used instead of silver films, on glass, ceramics, plastic, etc. are cheaper and claimed to be less easily tarnished. Data on decomposition of copper formate by hot glass (350-450C) *in vacuo*; of moist copper hydride in hot hydrogen or town gas; of copper carbonyl; chemical methods involving reduction of copper salts with tartrates, formaldehyde, sugars or hydrazine.—BNF. 9852

### 5.3.4

**Practical Bright Nickel Plating.** T. E. SUCH. *Bull. Inst. Met. Finishing* (Trans. IMF), 5, No. 1, 45-64 (1955) Spring.

Bright and dull plating and the merits of different fully-bright and semi-bright nickel plating solutions (with organic chemicals or cobalt salts as brighteners) are compared. Methods of controlling purifying these solutions and plant required; suggestions for appropriate cleaning cycles prior to bright plating (iron, copper alloys, etc.); points where techniques for bright plating differ from those applicable to dull nickel are discussed.—BNF. 9853

### 5.3.4, 6.3.15

**Molybdenum Deposition on Titanium.** S. TOUR, A. SYKA AND G. FISCHER. *J. Metals* (Trans. AIME), 7, No. 2, Sect. 2, 291-296 (1955) February.

Results obtained during research work involving coating titanium alloys with molybdenum by vapor-deposition methods. Techniques used to apply coating are described and results obtained from wear tests on molybdenum-coated titanium are given. Method can be used successfully to deposit hard adherent wear-resistant coating of metallic molybdenum on titanium and titanium alloys without changing microstructure of titanium base. Temperature and pressure are the most important factors in obtaining a sound deposit. Qualitative wear tests show remarkable wear resistance of molybdenum-deposited coatings on titanium and improvement over untreated titanium is especially pronounced when lubrication is used. Tables, photomicrographs, diagram, 4 references.—INCO. 9859

### 5.3.4

**Recent Developments in Chromium Plating.** H. SILMAN. *Metal Finishing J.*, 1, No. 1, 11-14 (1955) January.

Solutions including use of fluorides; self-regulating baths; obviation of cracks; sodium-tetrachrome baths; corrosion resistance; barrel plating, tampon plating.—BNF. 9812

### 5.3.4

**Deposition of Titanium Coatings from Pyrosols.** A. W. SCHLECHTEN, M. E. STRAUMANIS AND C. B. GILL. *J. Electrochem. Soc.*, 102, No. 2, 81-85 (1955) Feb.

A previous paper dealt with the formation of pyrosols (dispersions) of titanium by corrosion in fused salts. If sheets of copper and titanium are placed near to one another in a fused salt (e.g., sodium chloride or potassium chloride), it is found that titanium is transferred to the copper sheet, presumably by intermediate formation of a pyrosol. Coatings protected the copper from corrosion by nitric acid; iron, low-carbon steel, nickel, cobalt and copper-nickel (but not aluminum, cast iron or high-carbon steel) could also be coated.—BNF. 9819

### 5.3.4

**Tin Plating with Potassium Salts.** F. A. LOWENHEIM. *Tin and Its Uses*, No. 31, 7-10 (1955) April.

Advantages of the potassium stannate bath are summarized: plating speed, cathode efficiency, higher anode current density (stability of potassium stannate allows more free alkali to be present), use of Sn-1% Al anodes, application of potassium stannate bath (including immersion tinning of aluminum alloy pistons); tin alloy plating baths.—BNF. 10074

## 5.4 Non-Metallic Coatings and Paints

### 5.4.2

**Effect of Oxygen Content of Furnace Atmosphere on Adherence of Vitreous Coatings to Iron.** A. G. EUBANKS AND D. G. MOORE. National Advisory Committee for Aeronautics, Tech. Note No. 3297, May, 1955, 17 pp.

A series of vitreous coatings of the same basic composition, but with cobalt oxide contents varying from 0 to 6.4 percent by wt. was fired on ingot iron in atmospheres consisting of various oxygen-nitrogen mixtures. Nickel plating was applied in several cases to preserve interface inasmuch as coating had flaked off while section was being cut. Effect of oxygen content of atmosphere on adherence was determined by subjecting each specimen to ASTM adherence test and effect on interface roughness was estimated from examination of metallographic sections. Metallographic examinations showed a qualitative correlation between adherence and surface roughness regardless of oxygen content of firing atmosphere. Roughening of iron surface was attributed to galvanic corrosion. Tables, graphs, photomicrographs, 10 references.—INCO. 10018

### 5.4.2

**Direct Application of Finish-Coat Vitreous Enamels to Sheet Steel: Shop Practice.** B. ZICK. Paper before Symposium on Direct Application, Ann. Conf. of Inst. of Vitreous Enamellers, Manchester, October 7-9, 1954. *Metal Finishing J.*, 1, 33-36; joint disc., 36-42 (1955) June.

In enamelling of titanium-killed steel, nickel deposition is increased gram from normal 0.02-0.03 to 0.1-0.15-gram per sq. ft. (optimum 0.12-gram). Composition is given of solution for nickel deposition in Ferro-Republic process, in which nickel deposition should again be 0.10-0.15-gram per sq. ft.; i.e., 2-3 times that of galvanic nickel dip. B. K. Niklewski (Mair Enamel Mfg. Co., Ltd.) in dis-

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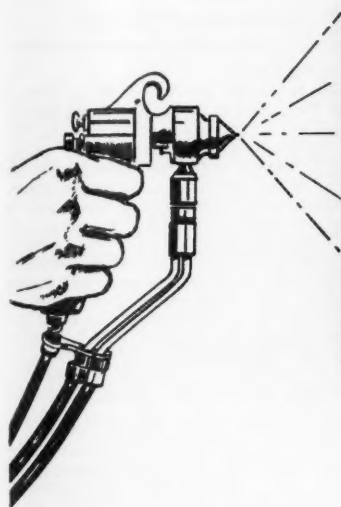
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cussion said that Nitec steel and ordinary metal with nickel dip both give excellent results.—INCO. 10207

#### 5.4.2, 2.3.7

**Apparatus for Automatically Recording Strains Between Enamel and Metal.** J. D. WALTON, JR. Paper before Am. Ceram. Soc., Enamel Div., 56th Ann. Mtg., Chicago, April 20, 1954. *J. Am. Ceram. Soc.*, **38**, No. 3, 114-118 (1955) Mar. 1.

Construction and operation of a mechanism for converting movement of an enamel split ring into a suitable electrical signal to be automatically recorded is described. Strain curves obtained when a commercially prepared titania cover-coat enamel was applied to previously ground-coated enameling-iron, cast iron, 302 stainless steel and Inconel rings are shown. Thermal expansion of enameling-iron, 302 stainless steel and Inconel at 30-330C, ring-movement values for each ring over same temperature range and calculated values of enamel thermal expansion are tabulated. Data were used to determine relationship between strains recorded and properties of metals. Strain curve of enamel applied to copper was also investigated. Mechanical failure of enamel when applied to copper and refired was due to permanent deformation of copper produced by enamel during initial firing. Two references.—INCO. 9877

#### 5.4.3

**Make Plastic Cores in Rubber-Lined Boxes.** R. F. DALTON. *Am. Foundryman*, **27**, No. 4, 46-49 (1955) April.

Advantages and procedures in making split rubber-lined core boxes; separating agents are not needed between core and plaster.—BNF. 9962

#### 5.4.5, 1.6

**The Chemistry of Synthetic Dyes and Pigments.** H. A. LUBS, editor. American Chemical Society Monograph Series No. 127, 1955, 734 pp. Reinhold Publishing Corp., New York.

American developments from the start in World War I through the assimilation of data obtained as a result of World War II.—BTR. 10080

#### 5.4.5, 3.8.4

**Water Absorption by Polymers.** J. A. ENDERBY. *Trans. Faraday Soc.*, **51**, No. 385, 106-116 (1955).

A theory of water absorption by polymers possessing strongly hydrophilic groups is developed by considering the statistical mechanics of an assembly of water molecules in a potential field provided by the polymer network. The configurational integral for the water molecules is evaluated by a general cell method, with no restriction on the number of molecules in a cell.—RPI. 10061

#### 5.4.5

**Production of Polyvinyl Esters by Ester Interchange.** E. W. ECKEY, R. O. ALDERSON AND R. J. WOESTMAN. *J. Am. Oil Chemists' Soc.*, **32**, 185-191 (1955) April.

Hydrogenated sardine oil, soybean fatty acids and cottonseed oil are tested as coating materials. Tables. 10 references.—BTR. 10060

#### 5.4.5

**Paint in Civil Engineering. Part I** ROLT HAMMOND. *Ind. Finishing* (London), **8**, 88-90, 91 (1955) February.

Surface preparation and selection of painting system to protect structures

subjected to industrial and marine atmospheres. Photographs. One reference.—BTR. 10052

#### 5.4.5

**A Review of Surface Coating Developments.** C. O. SCHWAHN. *Official Digest, Federation Paint and Varnish Production Clubs*, **27**, 63-82 (1955) Feb.

Progress report on important developments in protective coatings. Tables, photographs, graph.—BTR. 9818

#### 5.4.5, 7.7

**Are Plant Chemicals Trimming Life from Your Cables? Here's One Answer.** J. E. PARKER. *Carbide & Carbon Chemicals Co. Power*, **99**, No. 3, 132-135 (1955) March.

Where distribution cables are exposed to harmful chemicals, newer synthetic insulations, such as polyvinyl chloride and polyethylene with a polyvinyl chloride jacket are most suitable for preventing cable failures. Cable insulation must stand up under moisture, alkalies, acids, hydrocarbons (especially chlorinated hydrocarbons), elevated temperature and wear. Polyethylene insulation with polyvinyl-chloride jacket was found to be most satisfactory.—INCO. 9830

#### 5.4.5

**Possible Applications of Resin-Emulsion Paints.** (In German). B. SCHMUCKER. *Fette u. Seifen*, **57**, No. 5, 335-340 (1955) May.

Practical results of application for special purposes, e.g. for rust-proof coatings. Photographs, micrographs.—BTR. 9840

#### 5.4.5, 1.2.2

**Maintenance Painting in the Process Industries.** KENNETH TATOR. *Am. Paint J.*, **39**, 40+7 pages (1955) April 18.

Practical and economic aspects of this often neglected factor. Two references.—BTR. 9886

#### 5.4.5

**Factory Paints for Special Conditions.** W. L. YEO. *Corrosion Technology*, **2**, No. 5, 147-149 (1955) May.

Means by which paints protect a surface are summarized. Three main types of chemical-resistant coatings which at present are most frequently used are chlorinated rubber paints, air-drying epoxide resin enamels and cold-cured epoxide enamels. These three forms of protective coatings are discussed.—INCO. 9896

#### 5.4.5

**Mechanism of Corrosion of Plain and Painted Iron Objects.** (In German.) A. BUKOWIECKI. *Schweiz. Archiv angew. Wiss u. Tech.*, **21**, No. 4, 121-133 (1955) April.

Corrosive action of water and atmosphere: paint as a protective agent and its effectiveness on corroded surfaces; corrosion mechanism under paint. Tables, drawings, diagrams. 62 references.—BTR. 9942

#### 5.4.5

**The Protective Function of Paint Coatings on Metals.** P. J. GAY. *Electroplating & Metal Finishing*, **8**, No. 4, 153-156 (1955) April.

Function of coatings in protecting manufactured steel goods is discussed. Anti-corrosive primers, wash primers and phosphating, metal undercoats, finish paints and organic finishes are considered. Some of the properties of surface treatments and of paint coatings are de-

scribed with particular reference to electrochemical corrosion processes. Porosity effect of organic films is considered and effect of film structure on permeation by dissolved corrosive salts is emphasized. Paint coatings are to be regarded as complements to chemical surface treatments. 7 references.—INCO. 10008

#### 5.4.5

**Epoxy Coatings for Metal Decorating Finishes.** M. A. GLASER, E. J. BROMSTEAD AND G. L. WEAVER. *Official Digest, Federation Paint and Varnish Production Clubs*, **27**, 3-9 (1955) January.

Characteristics and applications. Tables, photograph.—MR. 9988

### 5.7 Treatment of Medium

#### 5.7.2, 3.2.2, 8.4.3

**Air Injection for Prevention of Hydrogen Penetration of Steel.** W. A. BONNER AND H. D. BURNHAM. *Corrosion*, **11**, No. 10, 447t-453t (1955) October.

The use of very small amounts of air for the prevention of hydrogen attack leading to blistering and fissuring of equipment is described. This protection is achieved by producing a small amount of polysulfide in situ which converts cyanide to thiocyanate and inhibits the primary corrosion reaction. The method has been used successfully for about two years. Inspections have failed to show any hydrogen damage to equipment protected by adequate air injection; no degradation of product quality has been observed.

In the application of the method, a number of problems arose which have since been solved. These difficulties include: 1) accumulation of oxygen in stagnant vapor areas, 2) accumulation of acidic ammonium thiocyanate leading to high corrosion rates, 3) control of pH in the desired range to prevent deposition of ammonium salts and to prevent decomposition of ammonium polysulfide, and 4) limited reaction rate between oxygen and hydrogen sulfide to form polysulfide.

Several methods are considered for the control of air injection to meet the polysulfide requirement in the system. Hydrogen penetration probes and chemical spot tests for ferrocyanide and free cyanide have been found adequate for this purpose. Complete protection against hydrogen damage has been attained by only infrequent adjustment of the air injection rates. 10313

#### 5.7.4, 5.6.3

**Smart Control of Humidity Licks Metal Corrosion During In-Process Storage.** A. M. BEEBEE, JR. *Power*, **99**, No. 5, 110-111 (1955) May.

Tests at Rochester Products (Div. Gen. Motors) showed that an area with a relative humidity of 40 percent or less is needed for safe storage of its steel tubing. Later results proved these tests were correct. All incoming air is dehumidified before it enters the controlled space. Hydrochloric acid, used as a cleaning agent prior toterne coating, is present in traces in the general manufacturing area. Pressurizing the storage room over the requirements imposed by dehumidification gives a positive means of preventing acid fumes from entering.—INCO. 9918

#### 5.7.6, 4.6.2

**New Way to Remove Feedwater Silica.** S. B. APPLEBAUM AND B. W. DICK-



# News about COATINGS for METALS

Metallic . . . . . Organic . . . . . Decorative . . . . . Protective

## Easy-to-use vinyl coating developed

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Their remarkable resistance to acids, alkalies, salts and other chemicals provides dependable protection for steel containers. In addition, they have the necessary physical properties to maintain this protection despite rough handling. They offer proper adhesion, and reverse impact resistance.

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All the well known corrosion resistance of vinyl-based coatings can now be obtained without the meticulous surface preparation normally required for such coatings. This is especially good news for plants that are continually plagued by the need for frequent maintenance painting due to corrosive conditions.

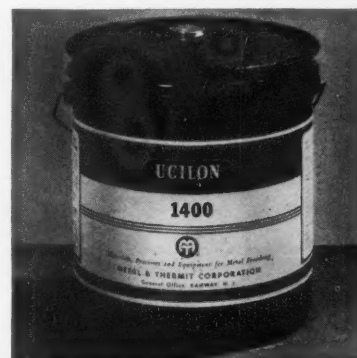
#### APPLY LIKE PAINT

Development of Ucilon Coating 1400 greatly simplifies application of a durable protective coating to walls, ceilings, floor and the exterior of equipment. It is self priming. Containing no ketone solvents, it goes over old paint without acting like a paint remover. Unlike other vinyl solution coatings, it has a mild odor and the extra safety of high flash point. Ucilon 1400

brushes out easily, and can also be sprayed.

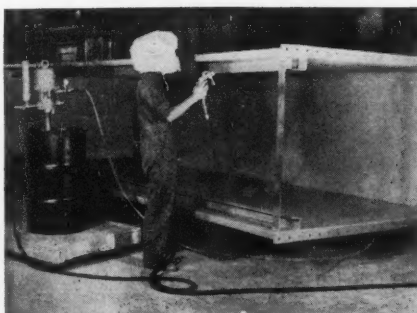
#### PROTECTIVE FEATURES

Ucilon Coating 1400 resists acids, alkalies, fumes, moisture and numerous other causes of early paint failure. Its use should help stretch the period between maintenance paintings and provide substantial economies. Send for data on this and other Ucilon Coating Systems.



Ucilon Coating 1400 is the newest in a broad line of protective coating systems that include vinyl, chlorinated rubber, vinyl-Thiokol, phenolic, neoprene, and fish oil based coatings.

### Plastisol ideal for protecting tanks



Large tank destined for electroplating service being sprayed with Unichrome Plastisol prior to being wheeled into baking oven for quick curing.

Because of its thickness (up to 60 mils per coat), chemical inertness and sprayability, the new Unichrome "Super 5300" Plastisol Coating makes superior tank lining. It can withstand continuous contact with severely corrosive solutions, save over the cost of applying sheet-type linings, and has no seams for corrosive solutions to penetrate.

Moreover, there now exist strategically located companies skilled in applying Unichrome Plastisol Coatings, and which have baking facilities to handle even large tanks. Send for names.

ERSON. Paper before Am. Power Conf., 16th Ann. Mtg. *Power*, 99, No. 4, 83-85 (1955) April.

Discusses salt-splitting anion-exchange as a possible method of removing silica from boiler feedwater. Studies for a 650-psig boiler plant indicate that this method is thoroughly practical. Table gives analysis of raw well water and expected analysis of treated water by demineralization, by hot-lime zeolite, by sodium zeolite plus salt splitter and by hydrogen-sodium zeolite plus salt splitter. Equations, flow sheet.—INCO. 9913

#### 5.7.6, 4.6.1, 4.6.13

**Ion Exchange in Water and Waste Treatment.** *Ind. & Eng. Chem.*, 47, No. 1, 46-101 (1955) January.

A symposium of 11 papers, including: Electrodialysis of Water Using a Multiple Membrane Cell, A. G. Winger and others (pp. 50-60); Electrolytic Regeneration of Spent (Steel) Pickling Solutions, H. C. Bramer and J. Coull (pp. 67-70); Anion Exchange Removal of Iron from Chloride Solution, A. C. Reents and F. H. Kahler (pp. 75-77); Treatment of Chromic Acid Wastes, R. F. Ledford and J. C. Hesler (pp. 83-86); Treatment of Spent Sulfuric Acid Pickling Liquors, A. M. Fradkin and E. B. Topper (pp. 87-90); Monobed Operation with a Problem Water (Production of High Quality Water for Chemical Laboratory Service), R. V. Skold and J. F. Wilkes (pp. 90-96).—BNF. 10049

#### 5.7.7, 5.8.2

**Neutralizers and Inhibitors Today.** R. J. HAFSTEN and K. R. WALSTON, Standard Oil Co., Ind. Paper before Am. Petroleum Inst., Ref. Div., St. Louis, May 9-12, 1955. *Petroleum Refiner*, 34, No. 5, 163-169 (1955) May.

Of several methods for combating corrosion, only alkaline neutralizers and inhibitors are discussed. Principal neutralizers in use are caustic soda, sodium carbonate, ammonia and ammonium hydroxide for low-temperature service. Lime is used primarily for high-temperature corrosion in thermal cracking units. Other neutralizers used in special cases include the petroleum phenols, naphthenic soaps and triethanolamine. Principal inhibitors in use are of the complex organic amine type. Ammonia is added to maintain a pH of 6.5-8.0. Tables give application of neutralizers alone, application of inhibitors to combat hydrogen attack and application of neutralizers and inhibitors.—INCO. 9989

### 5.8 Inhibitors and Passivators

#### 5.8.2, 4.6.1

**Control of Couples Developed in Water Systems.** G. B. HATCH. *Corrosion*, 11, No. 11, 461t-468t (1955) November.

The presence of copper and its alloys in water systems complicates control of the corrosion of the ferrous metals present with inhibitors. The solution of copper by the water on passage through the cuprous portions of the system and its subsequent deposition on the ferrous metal portions develops couples which are particularly difficult to control with inhibitors. A solution to this problem is offered by 2-benzothiazolethiol which can inhibit attack on copper and its alloys to an extent such that negligible copper is dissolved by the water. The factors involved in the use of this material in conjunction with the glassy phos-

phate inhibitors for steel were investigated. It was found that 2-benzothiazolethiol showed a tendency to interfere with many glassy phosphates used to protect iron and steel; when the compound was used in connection with Calgon T this was not the case. 10291

#### 5.8.2, 4.6.2, 7.4.1

**How Filming Amines Control Corrosion in Piping.** J. F. WILKES, W. L. DENMAN and M. F. OBRECHT. Paper before 17th Ann. Power Conf., Chicago, March 30-April 1, 1955. *Heating, Piping, Air Conditioning*, 27, No. 5, 129-131 (1955) May; *Nat. Engr.*, 59, No. 6, 20-23, 42 (1955) June.

Filming amines, applied in low, economical dosages, effectively control corrosion in steam condensate systems and on condensing surfaces, sharply reducing maintenance costs. Filming amine inhibitors increase heat transfer efficiency by removal of corrosion deposits and promotion of drop-wise condensation. Pitfalls to be avoided in filming amine application are discussed. Four case histories involving heat exchanger tubes in vegetable oil extraction plant, deaerating heater in paper mill, heating system in government hospital and dry kiln condensate lines in a group of lumber mills show some problems and results in amine application.—INCO. 9899

#### 5.8.2, 4.6.2

**Amines Protect Steam Plant Piping in Clinton Peabody Terrace.** H. BENOIST and M. E. DREYFUS. *Natl. Engr.*, 59, No. 2, 30-31 (1955) Feb.

Coravol steam system treatment consisting of volatile organic amines which circulate with steam and condensate and supplied by Western Chem. Co. has almost eliminated corrosion in steam systems condensate return lines and related equipment in power plant of one of St. Louis, Mo., housing authority's projects. Amines, distributed through entire circuit of steam and condensate, contacting all vapor and liquid sections and returning to boiler for evaporation and recirculation, neutralize acidity produced by carbon dioxide and provide protective alkaline condition for corrosion inhibition. Pitting and corrosion in steam and return lines has been eliminated and maintenance and repair costs have been greatly reduced.—INCO. 9937

#### 5.8.2, 8.4.3, 7.2

**Use of Ammonia to Prevent Casing Corrosion.** H. E. GREENWELL, RADO LONCARIC and HARRY G. BYARS. *Corrosion*, 11, No. 11, 491t-496t (1955) Nov.

The theoretical behavior of ammonia used as an inhibitor in the liquid phase of oil wells is surveyed. Laboratory experiments using a miniature well constructed of transparent plastic showed a special problem would exist if the ammonia were injected too fast, this resulting in formation of solid ammonium bicarbonate and carbonate.

Special injection equipment was constructed and used to inject ammonia into a well without difficulty of any kind. Analysis of produced fluids failed to show ammonia, so gas from treated wells was analyzed to determine distribution of the ammonia. Depths to which the wells were protected were calculated.

Authors say the experiments proved conclusively ammonia will penetrate below the zones of most corrosion; also that the rate of ammonia consumption is low and the reactions occurring should stifle corrosion. Authors' company is establishing a program for ammonia

treatment of all unpacked wells susceptible to internal casing corrosion in the vapor space. Cost is estimated at \$100 a year. 10297

#### 5.8.4, 4.6.2

**Experimental Boiler Studies of the Breakdown of Amines.** C. JACKLIN. Paper before ASME, Ann. Mtg., New York, November 29-December 4, 1953. *Trans. Am. Soc. Mech. Engrs.*, 77, No. 4, 449-452; disc., 452-453 (1955) May.

A number of amines and related materials were tested for possible use as corrosion-control agents in high-pressure boiler systems. Test equipment and procedure were set up to measure stability and pH increase. Results obtained from tests for breakdown to ammonia in an experimental boiler are reported. Test pressures ranged from 250-2500 psi and temperatures from 400 to 1200°F. Test results indicated that morpholine, which has been used successfully at 1600 psi and 1000°F, also shows relatively good stability at 2500 psi and 1200°F. Tables, graphs.—INCO. 10282

### 5.9 Surface Treatment

#### 5.9.1

**Preparation of Metals for Painting.** R. E. SHAW. *Corrosion Technology*, 2, No. 136-142 (1955) May.

Present-day techniques in the preparation of metals for painting are surveyed and sections on the testing of results, economics and design considerations are included. Degreasing with solvents, phosphoric acid cleaners, mechanical cleaning, phosphate coatings and chrome rinsing of steels are discussed. Preparation of aluminum, zinc, cadmium and magnesium surfaces prior to painting is covered briefly. Typical equipment layout and flow sheet for spray phosphating is sketched.—INCO. 9804

#### 5.9.2, 5.9.3

**Chemical Methods of Descaling and Derusting.** E. L. STREATHFIELD. Paper before Jt. Mtg. of Soc. Chem. Ind. & Royal Inst. Canada. *Corrosion Technology*, 2, No. 1, 23-24 (1955) Jan.

Rust and scale removed by mechanical and chemical means, with emphasis on chemical methods is discussed. Acid pickling with sulfuric acid, hydrochloric acid, phosphoric acid or tannic acid is covered. Electrochemical methods are described.—INCO. 9872

### 6. MATERIALS OF CONSTRUCTION

#### 6.4 Non-Ferrous Metals and Alloys—Light

**Hardening of Aluminum-Magnesium Alloys.** (In German.) OTTO DAHL and KLAUS DETERT. *Z. Metallkunde*, 46, No. 2, 94-99 (1955) Feb.

Behavior during annealing; structure, hardness, tensile strength and elongation; changes of thermoelectric power and electrical resistance for interpreting precipitation behavior. Micrographs, graphs, tables. Fifteen references.—BTR.

#### 6.4.2, 3.5.8

**The Interactions of Static Stress and Corrosion with Aluminum Alloys.** F. A. CHAMPION. *J. Inst. Metals*, 83, Part 8, 385-392 (1955) April.

Existing knowledge from laboratory experiments and service experience on



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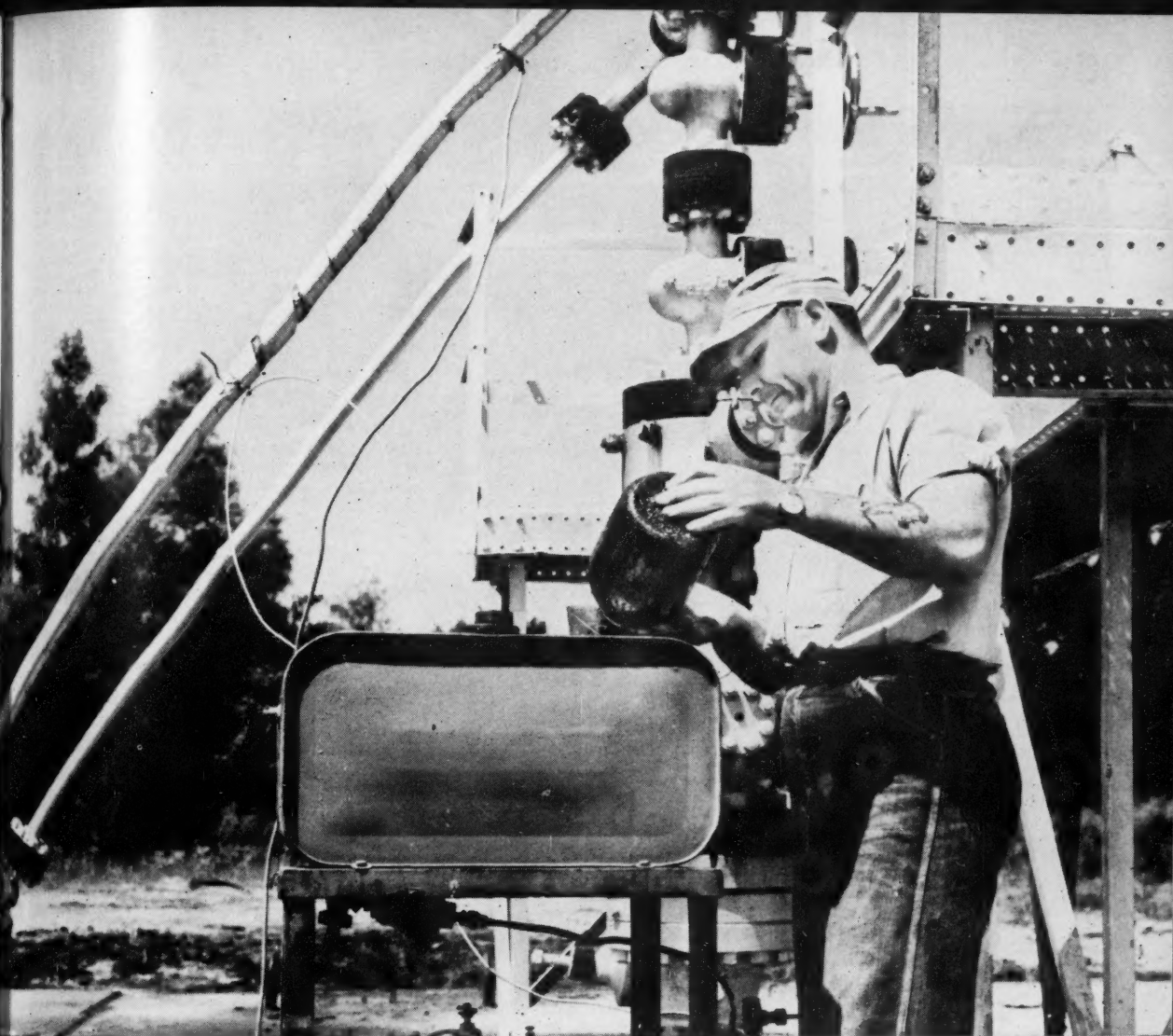
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the susceptibility of aluminum alloys to stress-corrosion and on methods of protection is reviewed, with particular reference to practical implications. It is important to distinguish between alloys that are liable to fail by stress-corrosion and those that are not. Precautions can then be taken in appropriate cases and unnecessary precautions and restrictions avoided in others. If precautions are taken with the few alloys that are susceptible, the risk of stress-corrosion failure in service is extremely small.—ALL. 9967

#### 6.4.2

**Finishes for Die Castings.** A. P. FENN AND L. A. J. LODDER. *Metal Finishing J.*, 1, No. 1, 23-28 (1955) Jan.

Chemical treatments as preparation for painting are normally based on solutions containing phosphates or chromates. The use of primers having a vinyl-resin vehicle pigmented with zinc chromate, to which are added thinners containing phosphoric acid may eliminate the need for any mechanical or chemical pretreatment. Paints containing salts of copper or mercury or metallic bronze or graphite powder and in certain conditions red lead are not to be recommended. For electroplated finishes the die casting first has to be coated with a preliminary zinc deposit. The techniques of the subsequent electroplating follow the specific requirements of different alloys. The color-tones obtained by use of the anodizing process are governed by the chemical composition of the acid bath and also whether AC or DC is used. Hard surfaces on aluminum alloys can be produced by direct chromium plating or by the production of hard anodic films.—ALL. 10199

#### 6.4.2, 5.3.4, 5.9.4

**Surface Treatment and Finishing of Light Metals.** 1) Part 10 2) Part 11. S. WERNICK AND R. PINNER. 1) *Sheet Metal Inds.*, 32, Nos. 333, 334, 335, 336, 35-41; 113-121; 189-195, 197; 273-283 (1955) Jan., Feb., Mar., Apr. 2) *ibid.*, 32, No. 337, 345-356, 372 (1955) May.

Part 10. January: Electrodeposition on aluminum and its alloys: metals deposited and difficulties encountered; surface preparation; etching and immersion coating (of nickel, copper, manganese, zinc, iron): electroplating on anode coatings (nickel, copper, cadmium, silver, etc.): details of phosphoric acid and Krome-Alume anodization. February: Various processes of hard chromium plating aluminum. Details of Vogt process and of BNFMR modification. In the March issue zinc immersion processes are discussed, including mechanism; effect of various solutions and alloy compositions; double zinc immersion technique. April issue gives brief details of plating with copper, brass, zinc, cadmium, nickel, chromium and precious metals after initial zinc film has been formed, also tin immersion deposits, immersion silver, electroless nickel plating, Alniclad process and carbonyl plating; adhesion tests, and detailed corrosion tests and results on electroplated aluminum; mechanical properties of plated aluminum, 81 references.

Part 11. Series is concluded with a discussion on hard anodic coatings with descriptions of MHC and the Hardas processes. Hardness, wear, corrosion and heat resistance, adhesion, fatigue and electrical properties are covered. Limited number of applications are reported. Tables, graphs and 17 references.—INCO. 10321

#### 6.4.2, 3.6.6

**The Use of Aluminium in Contact with Other Metals.** HUGH P. GODARD. *Eng. J. (Canada)*, 38, No. 1, 28-29 (1955) Jan.

The use of aluminum in contact with other metals is influenced by its environment. Where possible, it is best to avoid joining aluminum to copper or its alloys because this produces the most unfavorable galvanic couple likely to be encountered in practice with aluminum alloys, but if the couple is in a dry atmosphere there will be negligible galvanic corrosion. In all but marine atmospheres the galvanic action of mild steel and of wrought and cast iron on aluminum is slow. Copper-containing alloys such as 17S-T, 24S-T and 26S-T, suffer less galvanic corrosion in contact with steel and iron than alloys such as 2S, 3S, 57S and 65S. Aluminum performs well with stainless and chromium-plated steel. Aluminum may be used with lead in all but marine atmospheres. In the atmosphere, zinc is anodic to aluminum and will protect it when in contact. In alkaline solutions, zinc becomes cathodic to aluminum. Cadmium is very slightly cathodic to the common aluminum alloys (it is anodic only to the copper-containing alloys) and may be used safely with them. Magnesium is anodic to aluminum and corrodes preferentially when coupled. The resulting amount of corrosion in each case for a given combination depends largely on the conductivity of the electrolyte, the relative areas of the two metals and the electrical resistance of the joint.—ALL. 10319

#### 6.4.2

**The Corrosion Behavior of Aluminum.** HUGH P. GODARD. *Corrosion*, 11, No. 12, 542t-552t (1955) December.

The practical corrosion behavior of aluminum is reviewed for the non-specialist. Included is a discussion of the following topics: the relative nature of corrosion resistance, resistance criteria, factors influencing corrosion rates, common corrosion problems, how to choose an alloy; and galvanic, deposition, crevice and pitting corrosion. Specific information is given on corrosion in six major environments. Other topics considered include corrosion of brazed and welded joints, atmospheric performance of anodized aluminum and preventive measures.

Twenty-nine references are appended for persons interested in further study. 10315

#### 6.4.2, 3.5.8

**Anisotropic Loading Functions for Combined Stresses in the Plastic Range.** L. W. HU AND JOSEPH MARIN. *J. Applied Mechanics*, 22, 77-85 (1955) March.

Validity of loading functions for 24S-T in biaxial tension. Diagrams, graphs, table. 20 references.—BTR. 10048

#### 6.4.2

**The Galvanic Corrosion of Aluminum.** C. GROOT. Hansford Works. U. S. Atomic Energy Comm. Pubn., HW-33881, January 6, 1955, 28 pp.

The thermodynamics of the corrosion of aluminum are presented in potential-pH diagrams. These show that the hydrous oxides of aluminum have a minimum solubility near pH 6; the dissolution of the oxide film is the rate controlling step in the corrosion of aluminum, so this pH corresponds to a

minimum corrosion rate. Electrode processes which bring the pH nearer that minimum decrease corrosion, while electrode processes which bring the pH farther from that minimum increase rates. Thus, in acid solutions, aluminum cathodes are protected and anodes corroded, while in basic solutions anodes may be protected and cathodes corroded. In solutions just on the basic side of the pH of minimum solubility, galvanic effects on the corrosion of aluminum are of minor importance. (auth).—NSA. 9991

#### 6.4.2, 3.7.3

**Aluminum Brazing Sheet Reduces Fabrication Costs.** A. J. HAYGOOD. Aluminum Co. of America. *Elec. Mfg.*, 55, No. 4, 132-133, 348, 350 (1955) April.

Furnace brazing was chosen as most economical method for assembling tank and cover sheet metal parts of an electric steam iron with sheet aluminum body of thin gauge and reduced weight. Special brazing sheet—coated on one side with brazing alloy and on the other with a zinc-containing alloy—was employed to reduce manual placement of brazing rings. Corrosion problem in steam tank portion of iron was met by using standard Alclad 3003 sheet for tank hood and special brazing sheet for tank bottom. Since cladding is anodic to 3003 material, it will sacrificially corrode, under corrosive conditions, thereby protecting underlying metal. Photomicrographs of cross-section of Alclad sheet showing corrosion protection afforded by cladding, and cross-section of T-joint made from No. 100 Brazing Sheet are shown.—INCO. 10079

#### 6.4.2

**Aluminium and Its Alloys in 1954: Some Aspects of Research and Technical Progress Reported.** E. ELLIOTT. *Metallurgia*, 51, No. 304, 65-74 (1955) Feb.

Survey of research and technical progress including extraction, founding, fabrication, joining, constitution and properties, corrosion and protection, applications and standardization (in particular British Standards). 125 references.—BNF. 10064

#### 6.4.2

**Aluminum-Copper-Cadmium Sheet Alloys.** H. K. HARDY. *J. Inst. Metals*, 83, Pt. 7, 337-346 (1955) March.

Covers investigations of solution-treatment conditions, room- and elevated-temperature ageing characteristics, effect of cold-work before artificial ageing, annealing behavior and stress corrosion properties of aluminum-copper-cadmium alloys. Stress-corrosion tests were carried out on transverse test-pieces stressed as horizontal cantilever beams and sprayed each weekday with 3 percent sodium chloride solution. Fully aged alloys were immune from stress-corrosion and displayed intracrystalline attack when sprayed with 3 percent sodium chloride solution. Stress-corrosion occurred in these alloys when aged for three hours at 170°C. An aluminum-copper alloy with no cadmium, showed inferior resistance even when aged to its peak (40 hours) at 165°C. Both cadmium-free and cadmium-containing sheet materials were highly resistant when cold worked and aged to give peak properties. Experimental data are tabulated. Photomicrographs, 29 references.—INCO. 10051

#### 6.4.2

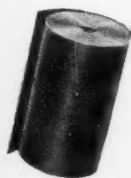
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LETT. *Metallurgia*, 51, No. 304, 59-64 (1955) February.

The 99.99 percent purity aluminum which is produced by a specialized electrolytic process has characteristics which make it especially suitable for use where high corrosion resistance, good ductility and high reflectivity are required. In architecture super purity aluminum is used for chimney flashings, vent-pipe flashings, cavity flashings, bay tops, dormer tops and cheeks and damp proof courses. Thin sheets are being used for flat roofing. A potentially large application is for cable sheathing; other uses include electrolytic condensers, reflectors, decorative applications and super purity cladding.—ALL. 9808

#### 6.4.2, 3.7.2

**The Effect of Zinc in Aluminium-Silicon-Copper Casting Alloys.** F. H. SMITH. *Metallurgia*, 51, No. 303, 24-28 (1955) Jan.

The aluminum castings industry largely depends on wrought scrap for its raw material. Such scrap now contains higher zinc content and an investigation has been carried out to find whether this could be absorbed in the commonly used LM-4 alloy. An increase in zinc from 0.5-3.0 percent was found to have no substantial effect on room temperature mechanical properties or ageing characteristics. This work is paralleled by that of the BNFMA described in Report RRA 1042: *Metallurgia*, 51, No. 305, 115-119 (1955) Mar. This showed in addition that the increased zinc had no adverse effect on corrosion resistance or ductility, the latter being measured by a refined method of torsion testing.—BNF. 9843

#### 6.4.2, 7.1

**Aluminium Alloys as Bearing Metals.** (In German.) E. VADERS. *Aluminium*, 31, No. 2, 55-57 (1955) February.

Considers three types aluminum bearing alloys: soft alloys with lead, tin, antimony, etc.; hard alloys with proportion of hard intermetallic compounds; and alloys with high zinc content. Advantages of new alloy "Lagal" (high zinc, no details), suitable for bushings exposed to high thermal or mechanical stresses.—BNF. 9876

#### 6.4.2

**Finishes for Alcoa Aluminum.** Brochure, 1955, 48 pp. The Aluminum Company of America, 762 Alcoa Bldg., Pittsburgh 19, Pennsylvania.

Illustrated with many full color figures, the brochure gives information on mechanical, chemical and electrochemical methods of finishing aluminum. Paint lacquers and enamels also are covered. Processes are mentioned and results illustrated. No technical data are given. 9932

#### 6.4.4

**The Coating of Magnesium Alloys.** W. E. ALLSEBROOK. *Corrosion Technology*, 2, No. 4, 113-116 (1955) April.

Protection of magnesium alloys in marine and industrial environments: pure magnesium is corrosion resistant, but traces of aluminum, copper, iron, etc. increase susceptibility to corrosion rapidly; manganese increases corrosion resistance of magnesium-aluminum alloys. Cleaning of magnesium alloys; chromating to increase paint adhesion; anodizing; bright dipping; paints for magnesium alloys and testing of paints; decreasing fire risks; galvanic corrosion; mold

growth on painted magnesium alloys. 9 references.—BNF. 9912

### 6.6 Non-Metallic Materials

#### 6.6.4, 4.7

**Chemical Attack of Melting and Fluxing Media, and of Metals, on Graphite Crucibles.** (In German.) E. LOTZE. *Gieserei*, 42, No. 4, 85-88 (1955) Feb. 17.

Action of various metals on graphite; purposes of various types of fluxes and other media and their behavior towards graphite; examples of crucible failure; suggestions regarding safe use of fluxes.—BNF. 10082

#### 6.6.6

**Special Ceramic Material for Metallurgical Purposes.** (In German.) G. JAEGER. *Metall*, 9, No. 9/10, 359-366 (1955) May.

After a short general survey including a table showing numerous refractory materials (in classes such as oxides, silicates, nitrides, etc.) author discusses individually (in some cases in detail) the properties as refractories of beryllium oxide, magnesium oxide, calcium oxide, strontium oxide, barium oxide, aluminum oxide, lanthanum sesquioxide, yttrium oxide, titanium dioxide, zirconium dioxide, hafnium oxide, thorium dioxide, stannic oxide, vanadium trioxide-vanadium pentoxide, chromic oxide, uranium dioxide, CeS and ThS. For a number of these materials, tables are given showing their behavior towards various metals, etc. at high temperatures. Bibliography of 41 references.—BNF. 10280

#### 6.6.6, 3.5.9, 3.5.8, 2.3.7

**Symposium on Thermal Fracture (of Refractories).** American Ceramic Society and Massachusetts Institute of Technology. *J. Am. Ceram. Soc.*, 38, No. 1, 1-54 (1955) Jan. Eight papers presented at a symposium on thermal stress held on September 16, 1953.

Recommended Letter Symbols for Thermal Stress Analysis, W. D. Kingery (pp. 1-2); Factors Affecting Thermal Stress Resistance of Ceramic Materials, W. D. Kingery (pp. 3-15); Thermal Shock Testing, W. R. Buessem (pp. 15-17); Theory of Thermal Shock Resistance of Brittle Materials Based on Weibull's Statistical Theory of Strength, S. S. Manson and R. W. Smith (pp. 18-27); Thermal Fracture of Ceramic Materials under Quasi-Static Thermal Stresses (Ring Test), W. R. Buessem and E. A. Bush (pp. 27-32); Effect of Porosity on Thermal Stress Fracture, R. L. Coble and W. D. Kingery (pp. 33-37); Effect of Shape on Thermal Fracture, E. M. Baroody, E. M. Simons and W. H. Duckworth (pp. 38-43); Thermal Shock Analysis of Spherical Shapes, W. B. Crandall and J. Ging (pp. 44-54).—BNF. 10279

#### 6.6.7

**Rubber and Allied Substances as Anti-Corrosion Materials.** B. J. WILSON. *Corrosion-Technology*, 2, 107-112 (1955) April.

Natural rubber; synthetic rubber and rubber-like plastics including PVC, polyethylene, Saran, Teflon and Kel-F. Photographs, table. Eleven references.—BTR. 9890

#### 6.6.8

**Resistant Properties and Uses of Fluorocarbons.** F. F. JARAY. *Corrosion Prevention & Control*, 2, Nos. 3, 5, 21-25, 39; 25-27 (1955) March, May.

Chemical resistance, processing prob-

lems and applications of polytetrafluoroethylene (PTFE) and polyfluoromono-chloroethylene (PTFCE) are discussed. Properties of the fluorocarbons are tabulated.—INCO. 10300

#### 6.6.8, 8.4.3, 2.3.6

**Reports to Technical Unit Committee T-1J on Oilfield Structural Plastics. Part 1. Long Term Strengths of Reinforced Plastics Determined by Creep Strengths.** H. D. BOGGS. **Part 2. Microscopic Examination as a Test Method for Reinforced Plastic Pipe.** CARL DE GANAHL. *Corrosion*, 11, No. 11, 57-60 (1955) November.

Part 1. Creep affects reinforced plastics and is a paramount factor in the determination of long term strength of structural reinforced plastics. It was found that the resins used are the central factor in the long term strength of the product. Creep studies of a given structure using various resins indicate that many resins have the same quick bursting strength but the workable stress loads for long term life vary greatly and in direct relation to comparative values of the resins.

Bond failure, elongation failure and low tensile strength failure are discussed briefly. A method of measuring creep involving the use of an extensometer is given.

Part 2. Microscopic equipment having a magnification power of 20-120 diameters is suitable for distinguishing lack of adhesion in resin to glass from fracturing of resin where adhesion is still satisfactory. Reflected light when shown at 30-40 degrees to the surface of the sample and at right angles to the direction of glass fibers is useful in tests. Photographs are useful to a certain extent but the sample can be examined much better through a microscope with the naked eye. 10311

#### 6.6.8, 6.6.7, 8.8.1

**Organic Materials for Radiochemical Uses.** J. F. BENNETT. *Chem. Eng.*, 62, No. 4, 226, 228, 230 (1955) April.

Organic materials are frequently suitable for use with radiochemicals in chemical processing. Of the plastics, polyethylene is the most easily decontaminated. In general, the harder the plastic the more resistant it is to radiation damage. Plastics tend to become more brittle and retain their tensile strength. Rubbers become harder and lose their elasticity and tensile strength. Plastic materials suffer radiation damage principally by ionization and chain cleavage. Resistance of plastics and rubbers to various reagents and optimum temperatures ranges for various plastics and rubbers are tabulated. 6 references.—INCO. 9966

#### 6.6.8, 2.2.2, 2.3.2

**Weathering of Polyvinyl Chloride.** J. B. DECOSTE and V. T. WALLER. Paper before Am. Chem. Soc., Heating-in-Miniature, Newark, January 25, 1954, and New York, February 12, 1954. *Ind. & Eng. Chem.*, 47, No. 2, 314-322 (1955) February.

Natural and accelerated weathering tests show that PVC compositions can be formulated that are suitable for long-time outdoor service. Exclusion of sunlight from body of plastic is major formulation problem. This is achieved by use of lead salt stabilizers and light-shielding pigments. Weathering test setup and test data are presented. Tables, graphs, 22 references.—INCO. 9950

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## 6.6.11, 4.6.4

**Cooling Tower Wood Can Be Protected.** R. B. CONLAN. *Petroleum Engr.*, 27, No. 1, C13-C14, C16, C18 (1955) Jan.

Chemical attack of cooling tower lumber may occur due to high sodium carbonate content of circulating water and rapidity of attack is increased by presence of high alkalinity in water and high concentrations of an oxidizing agent, such as chlorine. Chemical attack is controlled by acid treatment of circulating water for control of pH and alkalinity. Preventive maintenance should include hosing down sections of tower where salts have deposited from total evaporation and periodic inspections. Biological attack, caused by presence of wood-destroying fungi, manifests itself in form of both surface attack and an internal biological attack. Proper steps should be taken to prevent chemical attack, thereby minimizing possibility of biological attack. Present research is being directed toward control of wood-destroying fungi by treatment of circulating cooling water. Possible use of wood preservatives is being investigated. Illustrations, graphs, 6 references.—INCO. 9959

## 6.7 Duplex Materials

## 6.7.2

**Progress Reports on Cermet.** F. W. GLASER. *Metal Progress*, 67, No. 4, 77-82, 138 (1955) April.

Cermet is defined as a combination of a hard phase (not necessarily a true ceramic) with a metallic binder. Metallurgical considerations; eutectic binding; mechanical specifications (stress-to-rupture, thermal shock, impact strength); available cermets (titanium carbides, metal borides, aluminides). Above temperatures at which superalloys fail, it is suggested that there is a promising future for nickel aluminides at 871°C, titanium carbide-base cermets at 982°C and borides up to 1149°C.—BNF. 10005

## 6.7.2

**Metal-Ceramic Interactions. Part V. Note on Reactions of Metals with Titanium Carbide and Titanium Nitride.** W. D. KINGERY AND F. A. HALDEN. *Bull. Am. Ceram. Soc.*, 34, No. 4, 117-119 (1955) April.

Reaction of titanium nitride and titanium carbide with iron, nickel, molybdenum, silicon, niobium, titanium and zirconium was investigated at 1600-1800°C. Reaction interfaces and powder mixtures were studied microscopically and by X-ray diffraction. Formation of a new phase, solution in the metal phase, penetration along grain boundaries and extensive solid solutions were observed in various systems.—BNF. 10286

## 6.7.2

**A Study of the Microstructure of Titanium Carbide.** H. BLUMENTHAL AND R. SILVERMAN. *J. Metals* (Trans. AIME), 7, No. 2, Section 2, 317-322 (1955) Feb.

Influence of ball-milling procedure, ball-milling medium, pressing procedure, and sintering procedure on microstructure of 80/20—titanium carbide/nickel were investigated. Five different titanium carbides were used. Microstructure, grain shape and grain growth are functions of powder production procedure, surface conditioning of particles and impurities either contained in original powder or acquired during ball milling. Ball-mill mixing and sizing in one operation leads to thoroughly nickel-coated particles in contrast with poorer nickel

to carbide distribution for separate operations. Explanation for "coring effect" based on assumption of oxide film and on chemical analyses, is offered. Tables, photomicrographs, 11 references.—INCO. 9971

## 7. EQUIPMENT

## 7.1 Engines, Bearings and Turbines

## 7.1.3.6.9

**Swedish Method of Counteracting Corrosion Damage to Engines.** J. GRINDROD. *Corrosion Technology*, 2, No. 3, 87-88 (1955) March.

Exceptional material destruction occurring in 2-stroke engines was of special concern and research showed that Diesel oils with high cetane numbers and electric plant with low insulation resistances were probably the main causes of corrosive action. Under such conditions, stray currents in the hull, piping and engines start electrolytic action and potentials initiate oxidation in which metal ions act as catalysts. After years of investigation, a counteracting device was developed which stopped electrolytic action as well as oxidation of lubricating oil.—INCO. 10013

## 7.1.3.5.8

**Investigation Into the Failure of Two 100 MW Turbogenerators.** SIR CLAUDE GIBB. Paper before Instn. of Mechanical Engrs. *Engineering*, 179, 246-248 (1955) Feb. 25; *Engineer*, 196, 236-237; 272-273, disc., 276-278 (1955) Feb. 18, Feb. 25.

End bells of turbo-generators should be of non-magnetic materials. Most widely used material is austenitic steel (0.64-0.7 carbon, 0.37-0.45 silicon, 7.23-8.18 manganese, 3.8-4.09 chromium, 8.4-8.83 nickel). Alternative alloys and materials considered include titanium and a variety of nickel-copper (Monel) alloys. Details are given of forging technique used for Toronto end bells. Fatigue limit of failed end bell under alternating stress was 21 ksi, indicating a ratio of fatigue limit to uts of 0.35, as compared to 0.46 in heat-treated steel. Failure could be brought about by relatively small number of cycles of stress of about same order of magnitude as occurring in service. Drop of impact strength with temperature was not considered relevant to present investigation. No metallurgical reason can be given for explosive failure of the end bells, but on exciter end, the cross-over connections between the coils blanked off certain ventilating holes which were, therefore, not drilled. This may have increased stress by not more than 1 ksi at hole where failure was initiated and have determined the actual plane of fracture.—INCO. 10017

## 7.1.7.3

**Production of the Aircraft Turbine Engine.** K. T. FULTON. *Aeroplane* (Gas Turbine Number), 88, 301-311, 314-324 (1955) March 11.

Details of blade, disc, casing, ring and sheet-metal production processes and materials. Mond work, evolution of materials for forged blades (Stayblade to Nimonic 90—creep properties), benefits of Wiggins extrusion process and performance of Nimonic 95, use of Wiggins alloys in multi-stage turbines, Jessop's alloys (G.32, G.42B, G.40—compositions and uses), Firth-Vickers 467 steel in Viper and use of cast blades are discussed. Only British alloy specifically

developed as casting material is Jessop's G.34 (properties same as wrought G.32). Compressor blade materials (compositions, makers, properties, uses and performance) include Hiduminium RR series, SAP, nickel-aluminum-iron bronzes to DTD 197A, Hidurax 1/12A, Narramac, Firth-Vickers 448, R. ex 458, Firth-Vickers F.G. steels, Samuel Fox steels including Jethete M.160, Jessops steels and titanium alloys. Blade forging processes are described. For turbine nozzle blades, types and characteristics of precision-cast, rolled and extruded materials used (compositions given) are disclosed, including Firth-Vickers H.R. Crown Max, Nimonic alloys, Jessops R.22, G.19, G.34, G.39 and R.22, Hadfields Hecla Em.35, MM.35, Era HR6W, and 2 special nickel-base alloys. Processes involved in production, with special reference to precision-casting are discussed. Acetes and Pollock and Mond-Wiggins work on hollow and cooled blades, extrusion process at Wiggins and Garrington's method for production of hollow rotor blades (use of stainless steel and Nimonic alloys) are described. Compositions, properties and makers of aluminum alloys, alloy steels and titanium alloys, now used for compressor discs are given. Grades and properties of spheroidal graphite iron used for compressor casings are shown. Development of shell molding process for compressor casings is no doubt related to use of spheroidal graphite iron. Materials for circular and ring components are listed and their production described, including Sejourment process. Special components are fabricated from Nimonic 75, 80 and 90. The most popular material for flame tubes is Nimonic 75. Improved performance from Nimoply is discussed.—INCO. 10020

## 7.1.1.6, 7.3, 7.4.1, 3.5.9

**Gas Turbine Principles and Practice.** SIR HAROLD ROXBEE COX, Editor. Book, 1955, 960 pp. George Newnes Ltd., Southampton St., London, W.C.2.

This book contains 30 separately-paginated sections, varying in length from 2 to 120 pages, and written by 24 specialist contributors. It covers thermodynamics, mechanical aspects of design, compressors, turbines, fuels, combustion, heat exchangers, aircraft and other applications, educational facilities, etc. The sections of most interest to the metallurgist are: Materials of Construction, C. G. Conway (basic requirements; properties of materials for blades, combustion chambers, discs, etc.); cooling problems, survey of creep data, use of refractories, testing, corrosion, fabrication); Steady Stresses in Gas Turbine Components, P. H. W. Wolff; Vibration, J. R. Forshaw; Ash Deposition—Petroleum Fuels, H. Rowling; Fuel Ash Deposition, Corrosion and Abrasion—Solid Fuels, T. F. Hurley; and Industrial Process Applications, R. I. Hodge.—BNF. 9955

## 7.1

**Precision Type Automotive Engine Bearings.** I. M. CAMPBELL. *Australasian Engr.*, 1955, 63-69, March 7.

Development, application and fitting of bearings are covered. In discussing bearing characteristics, factors such as fatigue strength, corrosion resistance, embeddability, conformability and mechanical strength are considered. Most common bearings in use today comprise the tin-base and lead-base alloys, the copper leads, cadmium-nickel, cadmium-silver, with aluminum and silver alloys coming into the picture. Each has its



application in bearing design. Brief description of the visual signs of copper-lead bearing failure give some indication of the causes of failure.—INCO. 9956

## 7.1.4.4.7

**All-Season High Performance Oil—Successful Developments at the Sunbury Research Station.** J. C. CREE AND J. G. WITHERS. *Automobile Engr.*, 45, No. 1, 21-28 (1955) January.

Description of new motor oil which eliminates seasonal changes and gives

highest performance under all types of service conditions. Viscosity, effect on fuel and oil consumption, anti-wear properties, oil stability, combustion chamber and piston deposits and cold sludging are discussed. Radio-active tracer methods were used to determine engine wear; metal removed from piston ring as corrosion products is carried back to sump by oil so that radio-activity of sump is directly proportional to engine wear. Chevrolet L4 high temperature corrosion test on copper-lead bearings

showed that the oil gave complete freedom from hot corrosion as compared with heavy corrosion found when typical regular grade oil was used. Low temperature corrosion test on copper-lead bearings is also described. Graphs, illustrations, 10 references.—INCO. 9951

## 7.1.7.3

**British Naval Gas Turbine.** G. F. A. TREWBY. Paper before ASME Metropolitan Sect., Power & Fuels Div. and Soc. of Naval Architects and Marine Engrs., Jt.

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Mtg., New York, April 27, 1954 and ASME, Power Div., Washington D. C. Sect., April 28, 1954. *Trans. Am. Soc. Mech. Engrs.*, 77, No. 4, 561-584; disc., 585-590 (1955) May.

General picture of current state of British naval gas turbine development, with a review of operating experience to date and lessons learned. Design and construction details of eight different turbines described are tabulated and cycle diagrams with operating pressures and temperatures are shown. Original compressor blades of Gatric Turbine were of R. R. 56 anodized by chromic-acid process. When it was found that blades had suffered local intercrystalline corrosion after 50 hours running time, blade material was changed to R. R. 57. Problem of compressor fouling from salt spray fog was overcome by installation of water-spray equipment on several of the turbines. Frequent water-washing proved desirable for corrosion prevention. Illustrations, 22 references.—INCO. 9881

## 7.1, 6.4.2

**Improved Aluminum-Tin Bearing Alloys.** E. A. LANCASTER. *Can. Metals*, 18, 2nd Issue, No. 6, 44-46 (1955) May.

Most promising of new bearing materials are the high tin, aluminum-tin bearing alloys developed in the labs of the Tin Research Inst. Addition of tin, together with copper, nickel and possibly silicon, has substantially improved anti-seizure characteristics. Properties of alloys containing 30 percent tin, with and without the addition of copper, were examined. Fatigue tests at room temperature and at 150C are reported. Similarly bearings made from these alloys were tested in the Underwood bearing testing machine at 115C and tests confirmed that these alloys are much more resistant to fatigue than babbit and have excellent anti-friction properties. Four references and table.—INCO. 10077

## 7.2 Valves, Pipes and Meters

### 7.2, 3.5.3, 5.11

**Failures of Ball-Valves and Their Remedies.** A. SOBOLEV. *J. Inst. Water Engrs.*, 9, No. 2, 208-222 (1955) March.

It is stated that 1½ million ball-valves have to be replaced every year. After a summary of existing knowledge, describes investigation on British Standard B.S.1212 valve, which is shown to have low hydraulic efficiency. Predominant cause of seating failure is cavitation erosion, not erosion by impurities in the water. Cavitation can be eliminated or reduced by suitable design of the waterway. Some examination has been made of a new experimental valve; it is found to have better performance than valves in general use.—BNF. 9807

### 7.2, 6.6.8, 6.6.7

**Optimistic Outlook for Plastic Valves.** R. B. SEYMOUR. Paper before Valve Mfrs. Assn., N. Y., September 14, 1954. *Chem. Eng.*, 62, No. 6, 280, 282, 284, 286, 288, 290, 292 (1955) June.

Wide selection of appropriate plastic materials of construction is now available for valve manufacture. Proper attention to physical and chemical properties of these products will aid in selection of appropriate material for valves for any specific service. Epoxy resins, furanes, phenolic resins, polyesters, cellulose acetate, butyrate, polyethylene, polyfluorocarbons, polyvinyl chlorides, Saran and

styrene rubber plastics are discussed. Relative resistance of these plastics to impact and various chemicals is compared. Non-plastic bodies have been cast from iron, stainless, Monel, nickel, Hastelloy B and C, lead, aluminum, tin and others. Table.—INCO. 9803

## 7.2

**When Stronger Line Pipe is Needed .... Pipeliners Will Get It.** A. B. WILDER. *Oil Gas J.*, 54, No. 1, 130-131, 133 (1955) May 9.

One of the new developments in the line-pipe industry is the production of seamless cold expanded pipe in sizes 16 to 26 inches od, which is being manufactured in the world's largest pipe mill at Lorain, Ohio. Pipe is produced in a Mannesmann type mill from solid billets up to 12¼ inches in diameter and is expanded in a rotary rolling mill. Expander plugs are builtup disks fitted with nickel-chromium iron alloy rings. Another new development is T-1 brand steel (0.85 nickel, 0.75 manganese, 0.50 chromium, 0.45 molybdenum, 0.30 copper, 0.25 silicon, 0.15 carbon, 0.05 vanadium, 0.030 sulfur, 0.025 phosphorus, 0.003 percent boron). Superior quality of T-1 steel is due to microstructure obtained on heat treatment and depends upon quenching to martensite with essentially no free ferrite in structure. Seamless pipe can be manufactured from T-1 steel by piercing and rolling on conventional seamless mills. Illustrations.—INCO. 9887

## 7.2, 3.6.6

**95% of Valve Repair Costs Are Laid to Corrosion.** W. G. ELLIS. Paper before Tech. Unit. Comm. T-4F on Materials Selection for Corrosion Mitigation in the Utility Industry, Los Angeles, November 18, 1954. *Corrosion* (News Section), 11, No. 2, 69-74 (1955) February.

Report on cost of repairing corroded gate valves in a municipal water filter plant. Corrosion is the result of galvanic action between cast iron and bronze, the metals used in valvet construction. 95 percent of repairs on 20-inch gate valves were caused by corrosion. In 3¼ years of operation, cost of corrosion on valves amounted to 68 percent of original investment. In five years of service, necessary repairs on new 20-inch bronze trimmed gate valve would make it equal in cost to one type of 20-inch Monel gate valve. In future installations, only valves mounted with Monel or stainless steel and high nickel cast iron are recommended. Graph, tables, illustrations.—INCO. 10205

## 7.2, 8.8.1

**Corrosion of Pipes and Protection Against Corrosion in Chemical Plants.** (In German.) H. KLAS AND G. HEIM. *Chem.-Ing.-Tech.*, 27, No. 5, 299-307 (1955) May.

Report of corrosion phenomena due to water, acids, lye solutions and gases and their causes are clarified. Survey offered of measures for protection against corrosion are divided in three groups: active protection, application of protective coatings, and selection of suitable materials for pipes. Diagrams, photographs, tables, graphs. 60 references.—BTR. 10288

## 7.2, 8.9.3, 8.4.2

**The New Gas Transmission and Distribution Piping Code. Part VI. Corrosion of Gases and Soils and the Prevention of Over-Pressuring.** F. A. HOUGH.

*Gas*, 31, No. 6, 129-130 (1955) June.

Discussion of new piping code briefly covers corrosion allowances, definitions of non-corrosive gas and soil, protective coatings and cathodic protection. Code prescribes that, if a corrosive gas is to be transported or if suitable means of preventing corrosion in corrosive soils are not to be provided, the thickness of the pipe shall be increased to provide an allowance for corrosion. Code committee was unable to agree on method of determining corrosivity of a soil. Since very few standard specifications either for the components of protective coatings or for the design and application of a coating have been developed by recognized and authoritative specification writing bodies the committee could not prescribe or recommend any specific coatings.—INCO. 10037

## 7.2, 6.6.8, 5.2.1, 4.5.1, 2.3.7

**Corrosion Prevention and Plastic Pipe Section.** *Gas*, 31, No. 3, 57-84, 127-140 (1955) March.

Papers include: Installation and Experience Data Pile Up As More Utilities Turn Toward Plastic Pipe, W. W. Clark; Long-Term Creep of Pipe Extruded from Tenite Butyrate Plastic, L. W. A. Meyer and R. J. Scogin; How to Replace Steel Mains with Plastic Pipe, C. H. Webber; An Introduction to Kralastic, P. M. Elliott; Plastic Pipe Subcommittee Progressing Toward Establishment of Standards, G. Corfield; For Cathodic Protection Power Rectifiers or Sacrificial Anodes?, R. M. Wainwright; Selecting a Holiday Detector, J. Rasor; The Factor of Soil Resistivity in Establishing Corrosion Control, B. J. Whitley, Jr.—INCO. 10007

## 7.2, 7.6.6

**Better Service from Digester Blow Valves.** E. E. FINSEL AND F. PRACEK. *Paper Ind.*, 36, No. 11, 1088-1091 (1955) Feb.

Selection of proper blow valve prevents loss of cooking liquor, over-cooking and blow-pit accidents. Erosion and corrosion can lead to serious problems; shock during blow-down causes leaks if valve materials cannot safely withstand impact loading. As a general rule and for specific parts, plain and alloy steels, Monel, stainless steel and precipitation-hardened tubing have longest digester service life. Types of blow valves, valve operators, lubrication, installation and care are covered. Illustrations.—INCO. 9996

## 7.2, 5.2.1

**Current Requirements for Cathodic Protection of Well Casing.** L. DE WITTE. *Oil Gas J.*, 54, No. 1, 109-116 (1955) May 9.

Interpretation of both open hole and inside casing spontaneous potentials surveys with regard to prediction and treatment of external casing corrosion is considered. Combined effects of spontaneous potential currents and local galvanic cells were studied. Some laboratory data are given on effects of hydrogen polarization potentials and a simple method of calculating magnitude of cathodic protection current requirements is described. Both theoretical derivations and iron loss calculations show that 5 amperes of cathode protection is totally insufficient for deep wells under corrosive conditions such as occur in fields in Ventura County, California. Tentative alternative methods to alleviate corrosion in such wells include use of bituminous coatings, removal of spontaneous

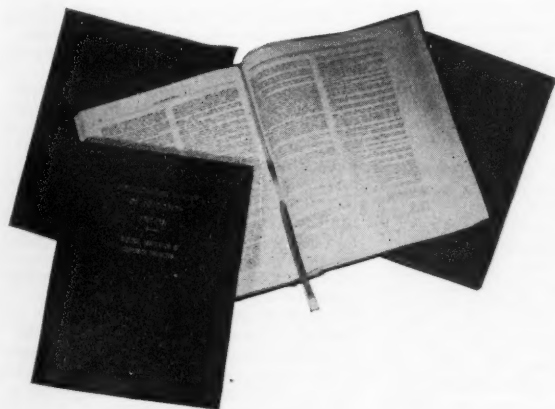
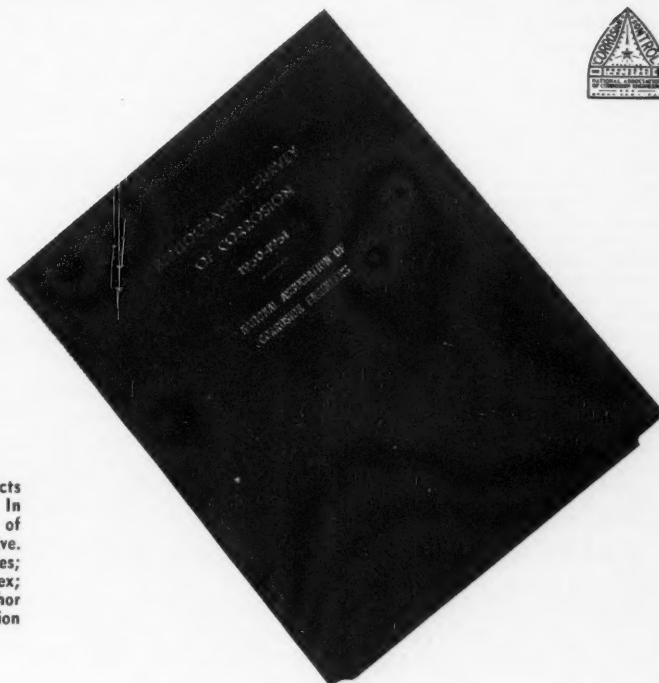
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potentials by conditioning mud, and careful selection of pipe in casing string. Table, graphs, 5 references.—INCO. 9981

### 7.3 Pumps, Compressors, Propellers and Impellers

#### 7.3

**Turnaround Pump Inspection.** W. D. ALLISON AND J. G. WALMSLEY. *Petroleum Refiner*, 34, No. 3, 160-164 (1955) March.

Causes of deterioration include mechanical wear, corrosion and erosion. Mechanical wear is usual reason for replacement of equipment. Cases of improper and inadequate lubrication often cause failures. Effect of corrosion and erosion is illustrated showing an impeller removed from a centrifugal pump handling a heavy oil-catalyst slurry. Severe erosion occurred because of large amount of solids in the oil. Effect of corrosion on a centrifugal compressor rotating element is illustrated. Third stage impeller vanes were corroded completely away. In pumps operating under conditions where hydrogen blistering is encountered, metal loss due to corrosion is slight, but a great deal of internal cracking and fissuring is often found. This occurs on cast carbon steel and other materials subject to blistering.—INCO. 9927

#### 7.3.7.2

**Chemical Feeding and Proportioning Equipment.** R. W. HENKE. *Badger Meter Mfg. Co. Ind. & Eng. Chem.*, 47, No. 4, 684-695 (1955) April.

Survey of field of feeding and proportioning liquid chemicals from application and equipment viewpoints. Typical fields of application are listed. Equipment includes piston or plunger-type pumps, diaphragm pumps, gear pumps and miscellaneous feeders. Tables give corrosion resistance of various materials found in commercial equipment to a detailed list of chemical media likely to be handled. Plastics; nonmetals (e.g. carbon/graphite, natural rubber, Neoprene); metal alloys such as Admiralty bronze, nickel silver, Monel, Hastelloy D and Waukesha 20; 9 AISI stainless steels and cast iron are among materials covered.—INCO. 10067

### 7.4 Heat Exchangers

#### 7.4.1, 3.5.3

**How to Select f-d, i-d Fans.** G. A. EATON AND R. H. SHANNON. *Power*, 99, No. 5, 88-91 (1955) May.

Key factors affecting choice of fans as well as their controls are discussed. Steps taken to eliminate corrosion on the gas side of air heaters often affect draft-system design. Hot-air recirculation increases air-heater tube- or plate-metal temperature, minimizing corrosion. When using regenerative type air heaters, flyash will have to be coped with at the f-d fan. Dust collectors—mechanical, electrostatic or a combination of both—are one of the best ways to minimize i-d-fan erosion. Critical erosion areas are the scroll, blades, center plate on a double-width fan and housing sides at outer edges.—INCO. 10058

#### 7.4.1, 4.6.4, 5.4.5

**How to Protect Cooling Tower Headers.** R. L. ELKINS AND G. O. HULT. Paper before Natural Gas Assoc. Amer., Dallas, April 13-15, 1955. *Petroleum Refiner*, 34, No. 5, 204-207 (1955) May; *Pipe Line Industry*, 2, 54-57 (1955) May.

Results indicate that protective coatings, if applied properly and in sufficient film thicknesses, can be employed to control corrosion of piping headers to cooling towers and thereby reduce maintenance expense. Vinyl, epoxy ester and modified phenolic resin systems were tested. To assure the quality of the coatings, it is believed necessary to follow the specifications when applying paints and reduce or eliminate water spray on coated headers.—INCO. 10057

#### 7.4.1, 4.6.13

**Heat Recovery in Graphite Heat Exchangers.** B. W. FREEDMAN. *Fuel Economy Rev.*, 33, 83-86 (1955).

Heat contained in corrosive type waste effluents can be recovered by using graphite or carbon heat exchangers; recent British design; examples of economies which can be achieved.—BNF. 9982

### 7.5 Containers

#### 7.5.5, 5.8.2, 8.4.3

**A Note on the Value of Ammonia Treatment for Tank and Casing Annulus Corrosion by Hydrogen Sulfide.** WALTER F. ROGERS. *Corrosion*, 11, No. 11, 488t-490t (1955) November.

Four-year tests of the effectiveness of anhydrous ammonia injections into the vapor space of tanks storing sour crude oil indicate that previously unexposed steel is protected for four to eight months. After this time, however, corrosion of the steel exposed to vapors from hydrogen sulfide containing crude proceeds at about the same rate in tanks with ammonia injections as those without it. Ammonia injections appear to have little beneficial effect when injected into tanks in which the steel already has been exposed to sulfide vapors. Analogous results are predicted from injection of ammonia into the casing-tubing annular space of sulfide producing wells. 10295

#### 7.5.5, 5.2.1, 4.6.3

**Protect Steel Tanks from Corrosion.** H. J. KEELING. *Petroleum Refiner*, 34, No. 2, 140-142 (1955) February.

Corrosion of steel storage tanks by brackish and basic waters is virtually eliminated by protective coating and cathodic protection. Rectifiers and galvanic anodes as power sources are discussed. Use of platinum, carbon, iron and magnesium for anodes in tank installation is reviewed and the merits of the various materials are compared.—INCO. 10290

#### 7.5.5

**Rising Cost of Storage Tanks.** C. V. LYNN. *Sinclair Ref. Co. Oil Gas J.*, 53, No. 45, 49, 104-106, 111-114 (1955) March 14, April 11.

Proper selection, sound construction, efficient upkeep and timely retirement are important considerations in dealing with oil-storage tanks. Fittings and attachments, painting and other maintenance and inspection and retirement of tanks are discussed.—INCO. 10078

### 7.6 Unit Process Equipment

#### 7.6.4, 4.6.2

**Corrosion of Steel in Boilers—Attack by Dissolved Oxygen.** H. A. GRABOWSKI. Paper before ASME, Ann. Mtg., New York, November 29-December 4, 1953.

*Trans. Am. Soc. Mech. Engrs.*, 77, No. 4, 433-441; disc., 441-448 (1955) May.

Reviews various theories that have been proposed to explain severe, although local, corrosion of furnace-wall tubes in high-pressure boilers. Failures characterized by presence of dark dense layer of magnetic oxide of iron, were embrittled at inner surface of tube. Results of field tests of oxygen record in utility-type boilers are presented. Metallurgical significance of failures and welding techniques are also discussed. Prevention measures include improved deaeration, addition of an oxygen scavenger, minimizing introduction of preboiler corrosion products into boiler and adjusting boiler-water controls. Illustrations, graphs, photomicrographs.—INCO. 9997

#### 7.6.4, 4.2.3

**Corrosion in Marine Boilers.** H. G. TERMAN. Paper before Jt. Mtg. Soc. Naval Architects and Soc. Marine Port Engrs. New York. *Mariner*, 2, No. 2, 36-37, 40-41 (1955) Feb.; *Marine News*, 41, No. 9, 30, 34, 40-41, 43 (1955) March.

Corrosion caused by deposition of sulfuric acid on metal surfaces of marine boilers which are below dew point of the combustion gases. Methods of counteracting corrosive effect are discussed. Reduction of sulfur content of fuel or removal of vanadium are normally not feasible. Rate of condensation or rate of acid deposition on surfaces below dew point is a more useful quantity than dew point in diagnosis of corrosion problems of boilers. Equilibrium diagram for sulfuric acid and water and conversion of sulfur dioxide to sulfur trioxide versus temperature are shown in graphs.—INCO. 10011

#### 7.6.5, 5.3.2, 4.3.2

**Corrosion of Lead-Lined Sulfuric Acid Evaporators: A Technical Note.** W. J. COTTON. *Corrosion*, 11, No. 11, 469t-470t (1955) November.

Two cases involving failure by corrosion of lead linings in sulfuric acid evaporators are reported. Case 1 involved an investigation of the reasons for a difference in service life of almost four to one between sheet supplied by two plants of the same manufacturer. The investigation showed the sheet failing in 18 months had a crystalline structure in which some crystals were 50 to 60 times greater in surface area than others. The smaller crystals appeared to be anodic to the large ones as pinholes in the sheet appeared to be at the location of the small crystals. The other sheet, which lasted seven years, was found to lack crystalline structure almost completely, indicating proper cooling technique.

Case 2 involved rapid disintegration of the lining of an evaporator into which prevailing winds introduced abrasive dusts from a nearby steel mill. It was postulated and proved in laboratory tests that the abrasive continuously removed the protective lead sulfate coating. When the evaporator was enclosed to exclude the dust, the trouble disappeared. 10293

#### 7.6.5, 5.3.2

**Stainless Overlays Combat Corrosion.** E. W. HOPPER. *Crucible Steel Co. Steel*, 136, No. 8, 74-77 (1955) Feb. 21.

Weld metal overlays of Type 310 stainless steel stop corrosion and erosion and extend service life of carbon steel Kraft digesters used by the pulp and paper industry. Technique for application of overlays is briefly outlined. Weld deposit is 0.100-0.125 in. in thickness. Illustrations.—INCO. 10038

7.7, No. 4, May. That have although tubes in charac- nise layer embrit- results of n utility- allurgical ing tech- revention aeration, er, mini- er corro- adjusting s, graphs, 9997

7.6.7 **Wet Screens.** H. L. BULLOCK. Bullock-Smith Associates. *Chem. Eng.*, **62**, No. 6, 185-190 (1955) June.

Wet screens used in the separation of solids from liquids are constructed of steel, stainless steel, nickel, Monel and bronze. Graphs.—INCO. 9978

7.6.8, 5.3.2

**Stops Corrosion From Sulfur Compounds, Hydrochloric Acid.** H. E. SMITH AND GORDON WEYERMULLER. *Chem. Processing*, **18**, 22-24 (1945) May.

How 410 stainless cladding solved problems at Humble Oil & Refining Co. pipe still. Photograph.—BTR. 9810

7.6.8

**New Unisil Stripper Improves Operation.** H. R. LYLES. Cities Service Refining Corp. Paper before Western Petroleum Refiners Mtg., Beaumont, February 11, 1955. *Petroleum Refiner*, **34**, No. 3, 207-209 (1955) March; *Oil Gas J.*, **53**, No. 44, 112-128 (1955) March 7.

Original stripper unit was constructed under wartime restrictions, Monel claddings or linings comprising up to 20 percent of the vessel wall thickness. Corrosion rate of 45-50 degrees Baume caustic on even Monel or nickel was appreciable at 290-300 F used in stripping. To minimize the maintenance problem the new stripper was constructed of solid 7/16-inch Monel walls which are expected to give long service even at the high corrosion rate of 0.02 in./year experienced at the most corrosive part of the tower. Tables and graphs.—INCO. 10071

## 7.7 Electrical-Telephone and Radio

7.7, 3.7.3, 6.4.2

**Metal Spinnings for Modern Communications.** J. M. FALCONER. *Sheet Metal Inds.*, **32**, No. 333, 25, 26, 28 (1955) Jan.

Spinning has been chosen as the most suitable method of fabricating parts for radio micro-wave transmission reflectors from aluminum alloys by Precision Metal Spinnings (Stratford-on-Avon) Ltd. A high degree of accuracy is needed over the whole surface up to about 14 feet in diameter. The material used for the mirrors is commercially pure aluminum in 10-swg thickness sheet, 1/2 H temper. The large circles are fabricated by gas welding the sections together. It was found that if pure aluminum welding rod was used, and the welds dressed and planished, bumping of the tool during the spinning operation was avoided. The argon-arc method of welding has also been found to give excellent results. No further annealing has been found necessary either before or during the spinning. The type of former or chuck used to support the work depends upon the number of reflectors required. For small numbers of systems, wooden formers have been used but metal formers permit greater accuracy of profile and better wearing properties. To stiffen the reflectors the edge may be rolled into a scroll, which is clamped to a steel bumper rim of slightly larger diameter. The supporting framework is preferably made from an aluminum alloy, such as AW.10.B, and is treated with an etch primer and cellulose paint. After several years in industrial and marine atmospheres, no evidence of corrosion has been observed.—ALL. 10019

7.7

**Flexible Air Dielectric Coaxial Cable.** J. S. BROWN. Andrew Corp. *Tele-Tech*, **14**, No. 5, 78-79, 126 (1955) May.

Heliac is a newly-developed coaxial line that provides desirable electrical properties of rigid air dielectric lines and approaches flexibility of solid dielectric lines. Copper inner conductor is supported by continuous polyethylene helix. Outer conductor is made of steel, copper-clad on inside to provide good conductivity. Outer conductor is helically corrugated, then coated with Polyment, a bitumen compound, over which insulating tapes are wrapped. Polyvinyl chloride jacket is extruded over outside. Adequate corrosion protection is provided by these two coatings. Illustrations.—INCO. 9941

7.7, 6.4.2

**Aluminium in Electrical Engineering.** J. C. BAILEY. *Metallurgia*, **51**, No. 304, 81-91 (1955) Feb.

Economic and technical merits of alu-

minum in the electrical industry. Application in overhead transmission lines, overhead low-voltage distribution, conductors in insulated power cables, fine-wire cables; cable sheathing (for copper- and aluminum-cored cables), aluminum alloy wire armour, bus-bars, telecommunications, windings; also used as wrought or cast parts for many pieces of equipment. 22 references.—BNF. 9916

7.7, 6.4.2, 6.3.8

**Aluminium Sheaths for Electric and Telephone Cables.** (In German and French.) J. P. WILD. *Aluminium Suisse*, **5**, No. 1, 9-25 (1955) January.

Survey of present fabrication position. Comparison of physical, mechanical and corrosion properties of aluminum and lead (also mentions lead-2 percent tin and lead-5 percent tin); jointing and repair of cables; laying of aluminum cables. Methods of sheathing cables: pulling cable into a larger aluminum tube and drawing to fit, direct extrusion and welding of aluminum strip; economic considerations.—BNF. 9900

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## 7.8 Wires and Cables (non-electrical)

### 7.8, 6.2.3, 2.2.2

**Barbed Wire Fence Still Good After 75 Years on Farm.** E. A. TICE. *Corrosion* (News Section), 11, No. 2, 103 (1955) February.

Sample of wire installed on Iowa farm 75 years ago represents early barbed wire made for farm use in U. S. and is traced to patents issued in 1875 to J. Dobbs & B. F. Moore, Victor, Iowa. Wire has suffered little metal loss, barbs being still tightly wound. Chemical analysis of wire revealed it to be a copper bearing steel (.35 copper, .28 manganese, .10-.15 carbon, .067 sulfur, .026 phosphorus, .02 nickel, .01 percent silicon) probably made by basic open hearth process, judging from its relatively low phosphorus content. Dense, protective, rust coating developed on wire has decreased its corrosion rate and many years of useful service could still be obtained from it. Illustration. 1 reference.—INCO. 10209

## 8. INDUSTRIES

### 8.3 Group 3

#### 8.3.4

**Corrosion in the Brewing Industry.** H. BARRON. Paper before Jt. Mtg. of Incorp. Brewers' Guild & Inst. of Brewing, October 1954. *Corrosion Technology*, 2, No. 4, 117-119 (1955) April.

Problems of corrosion in the brewing industry are discussed and suggestions

are expressed on best methods of protecting the various parts of breweries. Corrosive conditions prevailing are humidity, temperatures from 32°F in the cold room up to boiling in the coppers, pollution from carbon dioxide or sulfur dioxide, alkaline detergents, acid, residues of oxidized beer and sugars and yeast. Zinc-rich paints and epoxy type resins are used to cover exposed surfaces in the tun room, cellars, liquor tanks and bottling stores.—INCO. 9915

#### 8.3.5, 8.3.3

**Stainless Castings Guard Food Products.** E. A. SCHOEFER. *Steel*, 136, No. 8, 74-77 (1955) Feb. 21.

Cast austenitic chromium-nickel stainless steels are frequently chosen for food processing equipment because of their strength, ductility and good fabricating qualities. Stainless alloys do not affect appearance, taste or nutritional properties of food and are resistant to most cleaning chemicals, hot water, live steam and mechanical scouring. Large cast stainless bowl for collection of milk in automatic milk packaging machine, flowrator meters for ice cream making machine and heat exchanger for use in dairy operations such as pasteurizing are given as typical examples of austenitic stainless steel equipment. Molybdenum-containing cast stainless alloys are used by fruit juice processors for equipment such as extractor screw for pressing pineapple juice, because of excellent resistance to organic acids and cleaning chemicals. Compositions of stainless casting alloys popular in food industry are tabulated. Illustrations.—INCO. 9817

#### 8.3.5

**Corrosion in the Food Industry.** J. W. SELBY. *Corrosion Technology*, 2, No. 3, 71-74 (1955) March.

Survey of corrosion problems encountered in the handling and manufacture of food. Constituents of foods fall into one of four groups: acid-chloride group, which includes pickles and sauces; acid group which includes fruit products; neutral chloride group which includes meat and fish products; and neutral and relatively inert group which includes fats and cereal products. Toxicity of various elements, metal ions and flavor, choice of metals for equipment including 18/8 chromium-nickel steels with additions of molybdenum, 18-8, nickel, Monel, Inconel, aluminum and tin and non-metallic materials are discussed. Food factory structures are also covered. 7 references.—INCO. 9806

#### 8.3.7

**How National Starch Licks Corrosion.** D. GEORGE. *Chem. Eng.*, 62, No. 6, 120, 122 (1955) June.

Extensive use of corrosion-resistant materials for both process equipment and surrounding areas has paid off in lower maintenance costs and higher product purity at National Starch Products' new starch byproducts plant in Indianapolis. Centrifuges, filters, blenders, pulp press and conveyors used in the various operations for producing corn gluten meals and corn gluten feed are of Type 316 stainless steel. Flowsheet.—INCO. 10016

### 8.4 Group 4

#### 8.4.2

**Maintenance of Check Points in a Manufactured Gas Plant.** F. R. WAD-

LEIGH. *Gas*, 31, Nos. 4, 5, 52-56, 51-54 (1955) April, May.

In manufactured gas plant, coal is carried through the coke ovens and shaker screens to the point where it is conveyed to gas producers. Stainless steel liners were installed in triple hopper cars. Cast iron impellers on pumps were replaced with chromium-nickel alloy to withstand corrosive action of coke-quenching water which contains sulfur. Nickel steel wedges, used with flexible crane structure, allow a pair of wheels to drop out without the use of jacks. Centrifugal and reciprocating pumps handling a variety of liquids are constructed of Monel, stainless steel, bronze and cast iron. Anti-corrosive materials and an adequate painting program are good investments as atmospheric corrosion is a major cause of maintenance in this plant.—INCO. 9879

#### 8.4.3

**Improve Run Length of Solvent Refining Units.** E. G. HENDRICKSON. *Con-Cit Oil Corp. Petroleum Refiner*, 34, No. 3, 138-139 (1955) March.

Run lengths on solvent refining units can be increased by a preventive maintenance program, use of corrosion resistant alloys at points of severe corrosion, use of a sodium dichromate-sodium phosphate compound water treatment to minimize scaling in coolers and condensers and chemical injection to reduce corrosion.—INCO. 10056

#### 8.4.3, 4.2.3, 5.8.2

**Exhaust Gas Boosts Drilling Rate.** C. B. ERBE. *Carter Oil Co. Oil Gas J.*, 53, No. 42, 119-121 (1955) Feb. 21.

Application of exhaust-gas drilling is covered. Corrosion, one of principal problems, became apparent in the system although some success was obtained by using corrosion inhibitor. Test coupons indicated a corrosion rate of 11 mg./sq. dm./day in the low-pressure side and 70 mg./day in the high-pressure side of the system. But injecting the inhibitor in the high-pressure side too should alleviate this condition.—INCO. 10062

#### 8.4.3, 5.8.2, 5.7.7

**How Arkansas Fuel Oil Tackled Corrosion.** W. M. KYGER AND G. L. SHEPHERD. Paper before Natural Gasoline Assn. of Am., Ann. Mtg., Dallas, April 13-15, 1955. *Oil Gas J.*, 53, No. 50, 141-143 (1955) April 18; *Petroleum Refiner*, 34, No. 5, 213-215 (1955) May.

Corrosion of steel pipe, pressure vessels and other equipment in contact with sweet natural gas and hydrocarbons has been drastically reduced in East Texas and Panola plants of Arkansas Fuel Oil Corp. by use of a high-molecular-weight polar hydrocarbon-and-water-dispersal liquid organic inhibitor. Test criteria use to detect and measure corrosion action included corrosion rate coupons, water analysis for dissolved iron and copper and scale analysis. Severe corrosion at Panola inside water drain-pipe connections, where low-pH water is concentrated has become a serious problem. Attempts are being made to utilize alkalinity of boiler blowdown water to neutralize acidic components in hydrocarbon system, thereby reducing corrosion. Experimental data are tabulated.—INCO. 10083

#### 8.4.3, 4.6.1

**Oil Refineries and Corrosion by Water: Methods of Prevention.** P. W. SHERWOOD. *Petroleum* (London), 18, 50-53 (1955) February.

Three principal variables determine

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the degree of corrosiveness where attack by water is involved and six major methods are recognized for its control.—BTR. 9814

#### 8.4.3 Corrosion Control on Offshore Drilling and Producing Equipment. CHARLES

J. FRITTS. *Corrosion*, 11, No. 11, 471t-476t (1955) November.

Steel piling is preferred for offshore stationary drilling platforms because wood creates a fire hazard and stressed concrete may fail if salt water penetrates to the stressed reinforcement. Methods

used by one oil company to protect its platforms are described.

Specific recommendations are made for the three areas into which the platform is divided with respect to corrosion and for tenders and boats used in operations. For the atmospheric zone 10 or more feet above the water line a 6-coat



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minimum 6-mil vinyl system is recommended. Epoxy and hot spray vinyl systems are under test but not yet evaluated.

In the splash zone, from the water line upward 10 feet, design placing horizontal and diagonal bracing above or below this zone is recommended. Choice of methods of protecting this, the most corrosive zone, depends on the intentions of the company with respect to permanence of the platforms and other factors. Mentioned by the author, with costs per square foot, are Gunitite, Monel, porcelain enamel, sheet Neoprene, flame-sprayed polyethylene, plastic tapes over vinyl, metalizing, vinyl mastic systems and protective jackets.

Protection of submerged zone areas on fixed and floating surfaces by cathodic protection is recommended. Methods of using magnesium anodes are described. Bonding platforms and tender when tender houses welding machine positively grounded to the tender is recommended. 10326

#### 8.4.3, 6.4.2

**Aluminum in the Oil Industry.** H. M. BIGFORD. *Metallurgia*, 51, No. 304, 75-80 (1955) Feb.

The author reviews the use in the oil industry of wrought aluminum alloy in the form of sheet, strip, plate, tube and extruded section. General research experimental progress which might be of value to the industry is considered along with recent applications of light metals in this field. In the many phases of the petroleum industry such as exploration, extraction, transport, refining, and petroleum processing, the resistance of aluminum to corrosion by sulfur compounds and other aggressive agents and its other properties of light weight, strength, good weldability, excellent thermal conductivity and thermal transmittance make its use very advantageous. The recent successful use of aluminum for sea-going tanker heating tubes should extend its use considerably further.—ALL. 9945

#### 8.4.3, 8.8.1, 7.10

**Grounding, Bonding, and Lightning Protection in Oil Refineries and Chemical Plants.** E. C. BENJAMIN AND J. V. CUNDELAN. Paper before Am. Inst. Elec. Engrs. Petrol. Ind. Elec. Conf., Tulsa, September 27-29, 1954. *Elec. Eng.*, 74, No. 5, 400-403 (1955) May.

Review of various aspects of grounding practice. Current grounding practices usually call for installation of bare stranded-copper conductors for direct earth burial and copper-clad ground rods. Sacrificial corrosion of buried steel pipes or conduits occurs due to formation of galvanic corrosion cell in which steel pipe is anode while bare copper cable or copper-clad ground rods act as cathode. Preventive measures include providing grounding cables with insulating jacket, generally of Neoprene or other suitable plastic material, or substituting zinc rods or electrodes for copper-clad steel rods so that polarity of cell will be reduced and zinc will sacrificially corrode instead of steel.—INCO. 9921

#### 8.4.3

**Cut Corrosion in Dehydration Unit.** W. S. SWERDLOFF AND M. DUGGAN. Paper before Natural Gas Assoc. of America, Dallas, April 13-15, 1955. *Petroleum Refiner*, 34, No. 5, 208-212 (1955) May; *Oil Gas J.*, 54, No. 8, 91-94 (1955) June 27.

Magnolia Petroleum Co. disclosed experience obtained from five years of combatting corrosion in a diethylene

glycol gas dehydration unit. Corrosion was reduced in the rich and lean glycol solutions and dried gas lines. Corrosion test coupons showed considerable deposits of iron sulfide in the unit. Coupons seemed to corrode rapidly until a protective coating of corrosion products was formed. When temperature of gas was dropped, oxygen eliminated and higher percentage of inhibitor used, corrosion rate decreased. Contactor was also equipped with stainless steel. Flow diagrams and graphs.—INCO. 9869

#### 8.4.3

**Proposed Offshore Production and Gathering Facilities, Eugene Island Field, Louisiana Gulf of Mexico.** R. H. ILLINGWORTH, W. L. MONTGOMERY, C. ALDRIDGE AND C. V. TEMPLE. Paper before Am. Petroleum Inst., Div. of Production, 34th Ann. Mtg. *Offshore Drilling*, 2, No. 4, 8-9, 16 (1955) April.

Design and selection of supporting structures and platforms are considered. Supporting structures are constructed with concrete templet and concrete piling. Concrete was chosen since, according to studies, maintenance cost of steel structure (including cathodic protection) after 34 years will have used up saving in first-cost difference between steel and concrete structures. Templet columns or sleeves are tied together by steel pipe bracing which is wrapped with wire mesh and coated with concrete applied by spinning or rotating process, before incorporation into templet. After joining of jacket sleeves with bracing, all exposed steel joints are wrapped with wire mesh and concrete coating is applied by Gunitite process.—INCO. 10047

#### 8.4.3

**Oil Well Corrosion Can Be Licked.** S. A. HUCKLEBERRY. *Dowell Inc. World Oil*, 140, No. 5, 252, 254 (1955) April.

The two principal causes of corrosion of oil and gas equipment are classified as galvanic and chemical corrosion. Methods utilized for minimizing galvanic corrosion include use of sacrificial anodes, insulating flanges to electrically isolate pipe, standardization of metal composition in all well equipment and plastic coating of metal parts. Problem of chemical corrosion by naturally occurring acids in well fluids has been combatted by the use of chemical inhibitors to protect exposed metal surfaces. Principal methods used for evaluating efficiency of inhibitors are analysis of water samples, corrosion tests on metal coupons, running caliper surveys, using sub joints and visible inspection. Corrosion rate of high-pressure gas condensate well is discussed in typical case history illustrating use of an inhibitor to reduce subsurface corrosion. Economics of inhibitors are considered. Illustration, graphs.—INCO. 10039

#### 8.4.5

**Corrosion Is Stopping Reactor Progress.** R. C. GOLDING. *Modern Power & Eng.*, 49, No. 3, 130-131 (1955) March.

Corrosion particles in nuclear reactor water system become radioactive, making the effluent from the pipes dangerous material. Use of non-corrodible material and continuous passage of water through filters and ion exchangers is standard practice. Stainless steel is commonly used material for pipes but amount of corrosion taking place in stainless steels warrants stringent precautions. Corrosion must be held to 0.2 mils per year compared with 20 mils per year found in general run of piping.

Effects of pH, dissolved oxygen, heat transfer and velocity are considered. After 1000 hours use, water with pH 10 has double the corrosive effect of plain demineralized water. Graph shows effect of pH on stainless steel corrosion.—INCO. 10003

### 8.5 Group 5

#### 8.5.3

**1955's Maintenance News.** B. OTTS. *Paper Trade J.*, 139, No. 7, 24, 26, 45 (1955) Feb. 14.

Latest developments in pulp and paper processes, equipment and maintenance work organization. Wear prevention in pump bowls is being achieved by Neoprene and stainless steel linings and one mill specifies all stainless steel pump construction. Cast iron and Duriron are recommended for pumping of hypochlorite bleaches. Light gauge Monel is a popular material. As a general rule, 304 stainless steel should be used in paper mills and 316 in pulp mills. Stainless steel faces are recommended for cylinder molds subject to rapid corrosion.—INCO. 9829

#### 8.5.4, 4.4.2

**Acid-Resisting Steels in the Production of Wood-Vinegar.** L. WETTERNIK AND H. ZITTER. *Werkstoffe u. Korrosion*, 6, No. 6, 282-287 (1955) June.

Chemical attack of steel by wood-vinegar is more severe than by acetic acid. It is caused by homologous acids and empyreumatic substances. A steel with 18 chromium-10 nickel-2 percent molybdenum, generally used for acetic acid, failed. Improvement was attempted with steels of higher chromium and nickel contents. Best results were achieved with a 27 chromium-4.5 nickel-1.5 percent molybdenum steel, which has been used in the Swedish cellulose industry.—INCO. 9850

### 8.6 Group 6

#### 8.6.3

**Some Design Features of a Pilot Plant Continuous Range for Chemical Treatment of Cotton Yarn and Fabrics.** E. J. KEATING, A. S. COOPER, A. L. MURPHY AND H. O. SMITH. Paper before Am. Soc. Mech. Engrs., Texas Div., Atlanta, February 5, 1954. *Am. Dyestuff Repr.*, 44, No. 3, 65-68 (1955) Jan. 31.

Construction features and application of a continuous chemical processing range which comprises a group of basic textile finishing units. Padder immersion rolls of the combination padder-washer units are stainless steel. Rolls rotate in phenolic laminate bearings, fastened to stainless steel angles which are supported by stainless steel rods. Padder and washer tanks are also stainless steel. Illustrations.—INCO. 10306

#### 8.6.3

**Treating Cotton with Volatile and Toxic Chemicals.** L. H. GREATHOUSE, C. H. HAYDEL AND H. J. JANSSEN. Paper before Am. Chem. Soc., Regional Conclave, New Orleans, December 10-12, 1953. *Ind. & Eng. Chem.*, 47, No. 2, 187-191 (1955) Feb.

Reactor unit for treating cotton with ethylamine and acrylonitrile is described; stainless steel is used for making the central tube, distributor plate, thermometer well and packing gland in the reactor head. To overcome leaks developed by failure of gasket materials and thread pipe cements

as experienced in first experiment, extensive corrosion-resistance tests were conducted to select materials that would resist attack by ethylamine, acrylonitrile and acetylation solution. Plated coatings on steel began to deteriorate within 24 hours in acetylation solutions; no coating was found for carbon steel which would resist all three reagents. Results of series of tests on corrosion-resistant nickel alloys in block form with acetylation solutions are tabulated. Tables, 5 references.—INCO. 9995

## 8.6.3

**Corrosion Problems in Dyeing and Finishing Works.** A. J. HALL. *Fibres* (London), 16, 193-198 (1955) June.

Discussion of problems which may arise from corrosion of the building and structural elements, machines used in processing and adverse effects of corrosion products. Specific examples and reasons for their occurrence and improvements effected by hoods and covers for machinery are discussed. Monel has proved useful for dye vats and winches but is attacked by bleaching liquors and sulfur dye liquors and by various other liquors which contain sulfur compounds. Stainless steel is used almost exclusively in modern dye houses: Extreme importance of stain-resistance as distinct from corrosion-resistance in dyeing operations and advantages of stainless-steel in this connection. Old-type wood equipment with stainless steel linings gave trouble through corrosion of stainless steel by dye liquor accumulated between sheet metal and wood. This type of equipment has now been replaced by vats of all-stainless-steel construction. Behavior of stainless steel in contact with chemicals used for treatment of synthetic fibres is discussed. Strong bleaching liquor consisting of sodium hypochlorite attack stainless steel but they can be rendered passive to some degree by treatment with nitric acid solution.—INCO. 9983

## 8.8 Group 8

## 8.8.1, 4.3.3

**How to Choose Materials of Construction for Ammonia Synthesis.** W. G. DUDLEY AND J. J. MCKETTA. *Petroleum Refiner*, 34, No. 6, 169-170 (1955) June.

Ammonia can be made with little trouble if sufficient attention is paid to fundamentals of attack by hydrogen and nitrogen, sound engineering design, rigid inspection and specification of high quality materials and equipment. Under severe conditions, 18-8, 18-8+Ti, and 18-8+Cb are used to combat the hydrogen problem. Copper, nickel and nickel alloys are not subject to nitriding. Nickel and Monel are embrittled by intergranular attack. It is reported that Claude process cylinders are made of an alloy containing 60 nickel, 12 chromium and 2.5 percent tungsten, balance iron and that they have a life of 2000-25,000 hours. 5 references.—INCO. 10029

## 8.8.1, 4.3.5

**Multiple Cell Fluorine Plant—Improved Medium Temperature Fluorine Cell.** J. JACOBSON, W. K. HENDERSON, T. P. FLEMING, R. W. LEVIN, J. A. MARSHALL, J. DYKSTRA, S. KATZ, C. B. CLIFFORD, E. W. POWELL AND G. H. MONTILLO. *Papers before Am. Chem. Soc., Div. of Ind. & Eng. Chem.*, 126th Mtg., New York, September, 1954. *Ind. & Eng. Chem.*, 47, No. 5, 878-887 (1955) May.

Discussion of design and operation of new 36-cell fluorine plant with 2-ton-per-

day capacity operated by Carbide & Carbon Chem. under contract to Atomic Energy Commission. Each storage tank is equipped with 2 Fluorothene-coated Monel rupture disk assemblies for protection against excess pressure. Fluorine is pumped into steel surge tank. Shaft seals on pumps utilize copper-impregnated Teflon packing. Fluorine cells used, as compared with 1947 Hooker cell, have doubled cell operating current, doubled cell life and increased operating efficiency. Fluorine is liberated at carbon anode and hydrogen at steel cathode. Cell construction features welded Monel tank with steel water jacket. Chromium-molybdenum steel (AISI 4140) cap screws are used for anode support. Diaphragm assembly has Monel angle frame, screen, cap screws and reinforcement strips. Illustrations, 8 references.—INCO. 10281

## 8.8.1, 4.6.10

**Engineering in Salt Manufacture.** W. L. BADGER AND F. C. STANDIFORD. *Chem. Eng.*, 62, Nos. 3, 4, 173-177, 180-183 (1955) March, April.

Improvements in design and operation of conventional salt plants. Old salt evaporator was always made of cast iron with copper tubes. Today's construction consists of vapor heads of Monel-clad sheets, heating elements of Monel tubes and Monel tube sheets, internal piping of Monel or, in case of very large sections, Monel-clad steel. Monel is attacked by sulfur compounds, and most brines contain small amounts of hydrogen sulfide, but this can be removed by making the brine slightly acid and then blowing air in a packed tower. Newer and less orthodox processes of salt making are also covered. Diagrams, graph

and 14 references.—INCO.

9911

## 8.8.1

**Salt Manufacture.** A. S. HESTER AND H. W. DIAMOND. *Morton Salt Co. Ind. & Eng. Chem.*, 47, No. 4, 672-683 (1955) April.

Describes chemical engineering operations of Morton Salt Co. at Manistee, Michigan plant, largest evaporator salt plant in U. S. About 90 percent of salt output is made by vacuum pan process, remainder by grainer method. Body and tube sheets of vacuum pans are cast iron and tubes are copper. Cast iron parts must be renewed periodically because of corrosion, so that new vacuum pan installations will probably be constructed with nonferrous materials in contact with brine. Filters are fabricated from welded type 316 ELC stainless steel plates. Illustrations, 17 references.—INCO. 10069

## 8.8.3

**Modern Electroplating Plant.** W. H. SIMONS. *Metal Ind.*, 86, No. 17, 333-338 (1955) April 29.

Installation of new metal finishing plant in British factories over the past year. Materials of construction (rubber-coated steel, PVC, Polythene, fiberglass, etc.); introduction of heat exchangers; polishing and barrel finishing; methods of degreasing; automatic and barrel plating plant; anodizing equipment; rectifier equipment for electric power.—BNF. 9802

## 8.8.3

**High-Output Plating Machine Incorporates Job Shop Flexibility.** A. D'ACOSTA. *Iron Age*, 175, No. 23, 75-77 (1955) June 9.

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chines for job shop chromium plating was set into motion at Albert's Plating Works, Inc., Brooklyn. Although designed primarily to plate tubular furniture components, machine can be converted quickly for plating other parts. Plating cycle and layout are shown. During plating operation, the parts move continuously. At nickel plating tank, continuous circulation, filtration and external heating are functions performed in conjunction with a sump tank which is also used for solution makeup.—INCO. 9952

## 8.8.5, 6.6.8

**Continuous Pickling Stainless Steel—Sheffield Plant of Firth-Vickers.** F. F. JARAY. *Metal Finishing*, 53, No. 3, 68-72 (1955) March.

Detailed description of Firth-Vickers stainless steel pickling plant includes tank construction, acid storage, neutralizing and fume extraction. Neutralized strip is pickled in mixture of 3 percent hydrofluoric acid and 10 percent nitric acid on "hot" line and, after cold reduction, passes to "cold" pickling line. Polyvinyl chloride is used throughout plant—as liner and joint filler for cement tanks, pipes, valves, ducking rollers, hood liners and fume extraction ducts. Stainless steel is used for 2500 gallon nitric acid storage tanks and for valves.—INCO. 10309

## 8.8.5, 5.9.2

**Sodium Hydride Descaling.** D. J. FISHLOCK. *Product Finishing*, 8, No. 3, 59-62 (1955) March.

Plant used for descaling and the process itself are discussed in some detail; generation of sodium hydride inside the molten sodium hydroxide bath (1-2 percent sodium hydride); problems of plant corrosion. It is stated that there are now about 24 such plants in operation in Britain.—BNF. 9980

## 8.9 Group 9

### 8.9.1, 3.1

**Factors and Prevention of Corrosion.** C. L. HIBERT. Gen. Dynamics Corp. *Aero Digest*, 70, No. 4, 22-31 (1955) April.

Complete and accurate guide for the engineer faced with the problem of judging, designing against and preventing corrosion in aircraft. Besides descriptions of the mechanics of corrosion in one metal, between dissimilar metals and between metal and non-metal, there are tables on the comparative tendency of dissimilar metals structurally connected to corrode, on surface treatments required prior to finishing, on interior and exterior finish requirements, on finish of firewalls and interior surfaces on the engine side, and on applicable specifications for these finishes. Corrosives, corrosive forms, modes of corrosive attacks and protective measures are tabulated. Five references.—INCO. 10033

### 8.9.3, 7.2

**Why Ferrous Pipe Corrodes.** F. E. KULMAN. Consolidated Edison Co. of N. Y. Paper before Am. Gas Assoc. Distribution, Motor Vehicle & Corrosion Conf., Cincinnati, April 14, 1955. *Gas Age*, 115, No. 10, 26-29 (1955) May 19.

Based on a study of experience among 28 companies, an analysis of the several causes of corrosion and the relative occurrence of each is presented. Survey proved that corrosive soil accounts for

about 65 percent of all corrosion leaks in pipes; dissimilar metals 20 percent; and stray current electrolysis 15 percent. Most of replies to the survey urged the development of methods for detecting corrosive soil. Graphs.—INCO. 10070

### 8.9.3, 8.4.2

**Gas Pipe Line Deposits: Causes and Cures.** L. T. BISSEY. *Petroleum Engr.*, 27, No. 3, D28-D31 (1955) March.

Studies of natural gas pipe line deposits indicated that four main sources were internal corrosion, mill-scale, construction dirt and heavy hydrocarbons. Presence of water, hydrogen sulfide, carbon dioxide and oxygen in natural gas is responsible for the internal corrosion of natural gas pipe lines. In addition to the use of filters and scrubbers to pick up dust and heavy hydrocarbons, inhibitors and pipe coatings are used to control corrosion.—INCO. 9946

### 8.9.4

**Aluminum in Rolling Stock Construction—Use of Corrosion-Resisting Materials.** T. G. GRIFFITHS. *Ry. Gazette*, 102, No. 25, 711-712, 717 (1955) June 24.

Discusses the replacement of steel by aluminum in mineral wagons and makes a direct comparison of the cost of building and operating aluminum-plated and steel wagons. Replacement problem is reduced to an estimation of minimum thickness of plate and sheet that will stand up to the combined effects of mechanical and corrosion damage. Tables.—INCO. 10014

### 8.9.4, 5.5.2

**Rail Web Failures.** C. J. CODE. Paper before Metropolitan Maintenance of Way Club, New York. *Ry. Gazette*, 102, No. 6, 162 (1955) February 11.

Laboratory examination of rail failures and track tests on web stress at rail ends were conducted. Frequency of failures was greatest in tunnels due to combined effect of corrosion and of lower standard of joint-packing leading to development of corrosion-fatigue cracks. Type of moisture causing corrosion was among important factors in corrosion-fatigue life of rail. Fairly early failure took place in corrosive industrial atmospheres. General conclusion from tests was that many web failures could be explained by corrosion-fatigue but not by corrosion alone. Prevention measures included protection of rail ends against corrosion by coating with a rust-preventing grease.—INCO. 9961

## 8.10 Group 10

### 8.10.2

**European Vacuum Melting History and Practice.** H. H. SCHOLEFIELD. Paper before Jt. Mtg., Inst. Metals & Inst. Brit. Foundrymen. *Metal Treatment*, 22, No. 115, 141-147 (1955) May.

Review of past achievements and present trends in vacuum melting of metals. Various furnace designs, pumping equipment and operating conditions and procedures are discussed. Among practical problems which arise are metals having a relatively high vapor pressure at the melting temperatures, e.g. manganese in steels or nickel-base alloys, so that their partial vapor pressure is greater than the pressure in the chamber and they therefore vaporize. Need is felt for continuous charging and casting without the necessity for breaking the vacuum in the melting chamber. Diagrams and 10 references.—INCO. 9985

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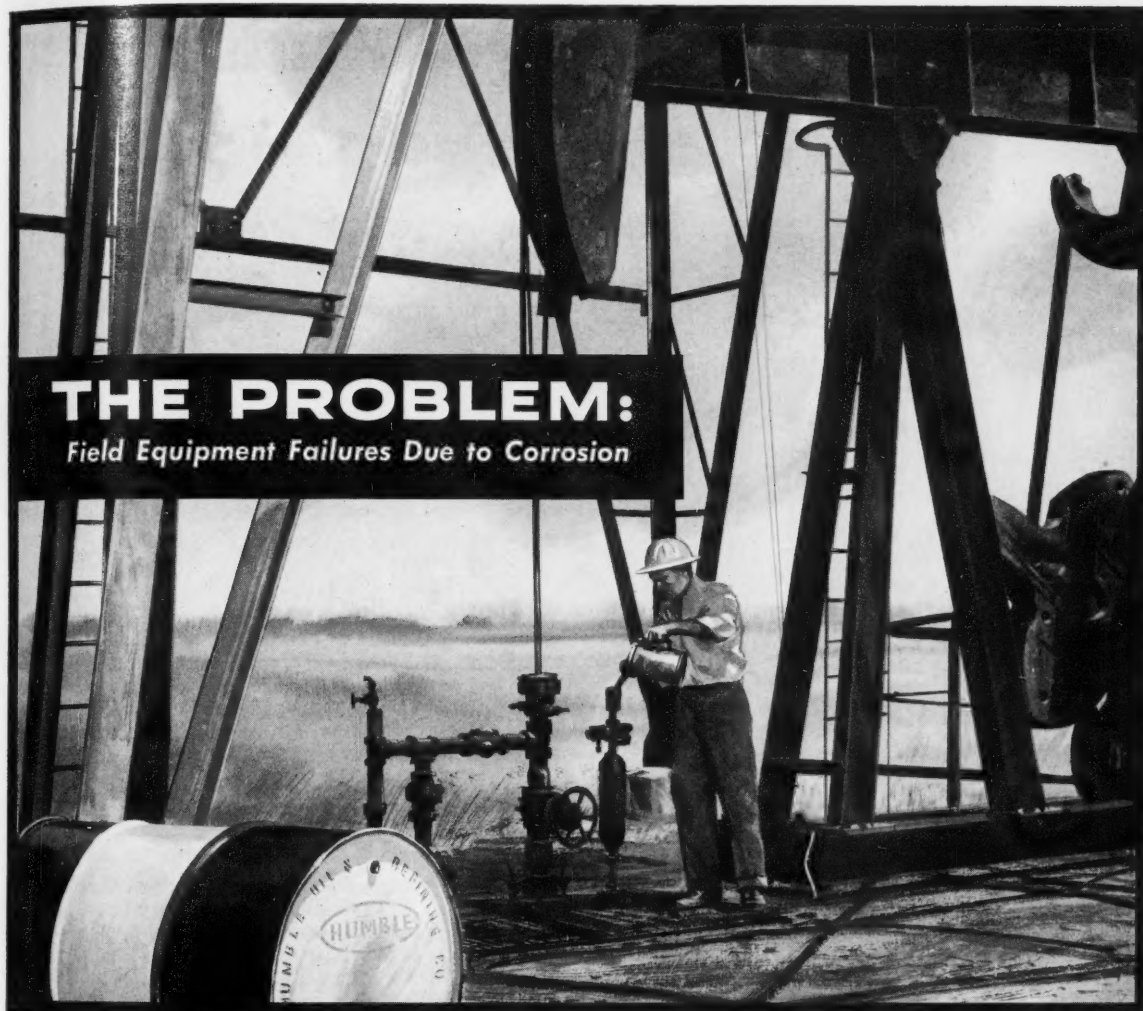
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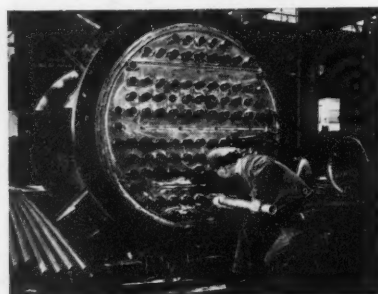
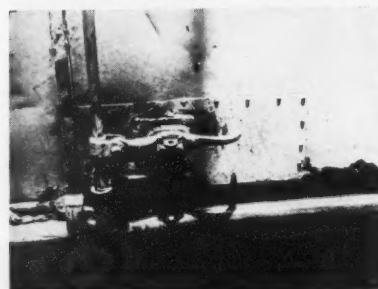
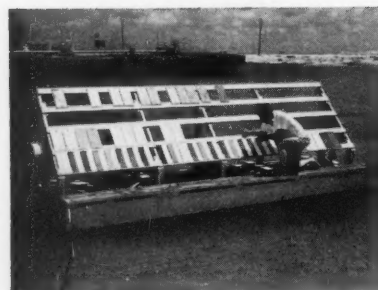
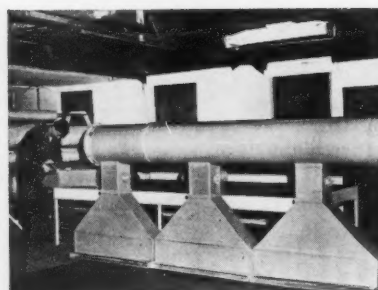
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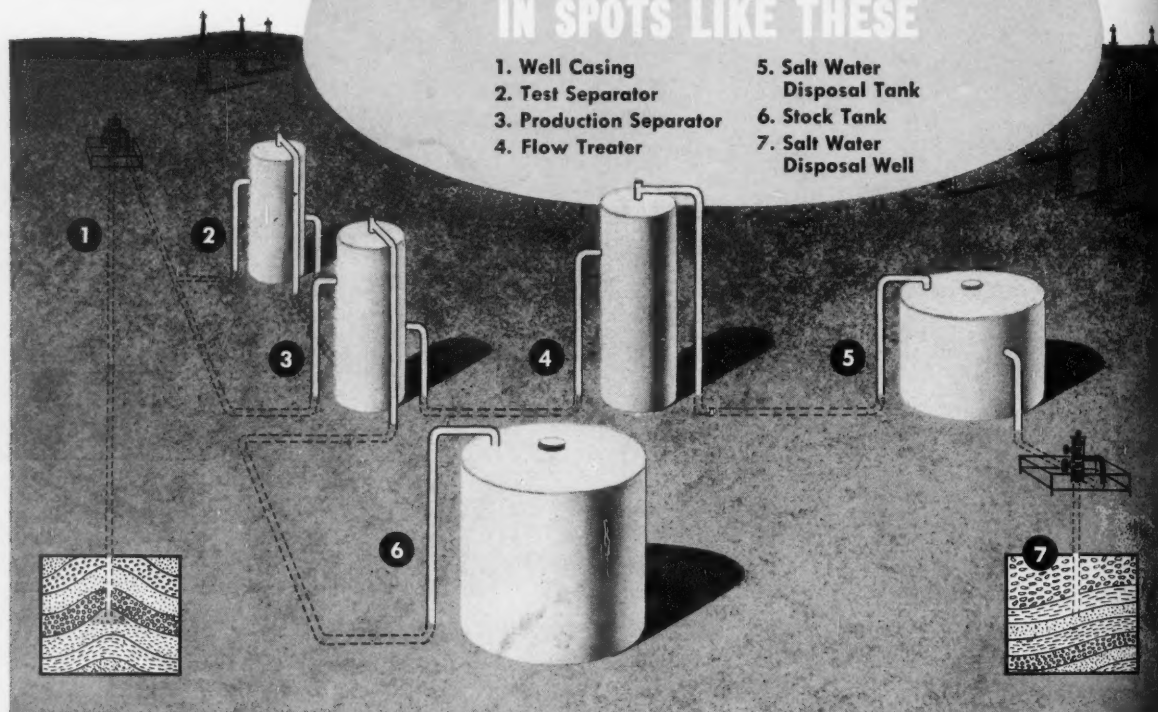


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